



# Is susceptibility to E-cigarettes among youth associated with tobacco and other substance use behaviors one year later? Results from the PATH study



Nicole E. Nicksic\*, Andrew J. Barnes

Center for the Study of Tobacco Products, Department of Psychology, Virginia Commonwealth University, Richmond, United States of America  
Department of Health Behavior and Policy, Virginia Commonwealth University, Richmond, United States of America

## ARTICLE INFO

### Keywords:

Electronic cigarette  
E-cigarette  
Cigarette  
Susceptibility  
Youth  
Tobacco use  
Substance use  
Cohort

## ABSTRACT

E-cigarettes are the most commonly used tobacco product among youth. In addition to harm potential, e-cigarette use is associated with initiating cigarette smoking. Limited research exists whether susceptibility to e-cigarette use is a risk factor for future tobacco and other substance use initiation. This study examined associations between baseline e-cigarette susceptibility and initiation and past 30-day use of e-cigarettes and cigarettes as well as initiation of marijuana and alcohol one year later, after adjusting for other risk factors and sociodemographic confounders. The study sample consisted of 5156 nationally representative youth (12–17 years) who completed both waves 1 (2013–2014) and 2 (2014–2015) of the Population Assessment of Tobacco and Health (PATH) study and were never users of tobacco, marijuana, and alcohol in Wave 1. Youth who were susceptible to e-cigarettes had increased odds of initiating e-cigarettes (adjusted OR: 2.22, 95% CI: 1.55–3.18), marijuana (aOR: 1.66, 95% CI: 1.12–2.46), and alcohol (aOR: 1.61, 95% CI: 1.26–2.06) between waves, as well as past reporting 30-day e-cigarette use (aOR: 3.64, 95% CI: 1.93–6.89) in Wave 2. Additionally, cigarette susceptibility, but not e-cigarette susceptibility, was associated with cigarette initiation (aOR: 3.36, 95% CI: 1.95–5.82) and past 30-day use (aOR: 2.83, 95% CI: 1.34–5.97). Prevention policies, as well as future research, could target youth susceptible to e-cigarettes to reduce the current trends on the use of these alternative tobacco products. Such efforts may also reduce the use of cigarettes and other substances.

## 1. Introduction

While cigarette smoking has declined among US youth, electronic cigarettes (e-cigarettes) were the most widely used tobacco product among middle and high school students in 2016 (4.3% and 11.3% in the past 30 days, respectively) (Jamal et al., 2017). Commonly, e-cigarettes contain nicotine, an addictive chemical that is harmful to adolescent cognitive development and leads to dependence (Krishnan-Sarin et al., 2015). Additionally, youth who use e-cigarettes may transition to cigarette smoking (Leventhal et al., 2015; Primack et al., 2015; Watkins et al., 2018; Barrington-Trimis et al., 2016). Understanding the influences of susceptibility to e-cigarette use on smoking and other substance use behavior is imperative to tobacco control strategies moving forward. Susceptibility, a validated measure in cigarette smoking, is defined as the lack of a firm commitment to not use cigarettes and has been associated with cigarette initiation over time (Pierce et al., 1996). In the progression to frequent use, being susceptible to future cigarette smoking precedes initiation and can last for several years (Pierce et al.,

1996; Messer and Pierce, 2010; Strong et al., 2015). Recent literature has examined susceptibility to e-cigarette products among youth (Krishnan-Sarin et al., 2015; Bold et al., 2016; Case et al., 2017; Nicksic et al., 2017; Trinidad et al., 2017; Pierce et al., 2018; Kwon et al., 2018; Carey et al., 2018; Pierce et al., 2017), yet further longitudinal research is needed to document whether susceptibility to e-cigarettes is a risk factor for tobacco and other substance use behaviors in the future.

There is limited evidence on youth e-cigarette susceptibility generally, and few studies exist on the associations between e-cigarette susceptibility and future e-cigarette. No known studies have analyzed e-cigarette susceptibility and future cigarette and substance use behaviors using a nationally representative prospective cohort of youth. Prior work determined susceptibility to e-cigarettes among youth was associated with initiation and past 30-day use of e-cigarettes 6 months later; however, this sample included students from only one state and did not assess the use of other products (Bold et al., 2016). A nationally representative study determined that susceptibility to either e-cigarettes, cigarettes, cigars, or smokeless tobacco predicted ever use of the

\* Corresponding author at: Virginia Commonwealth University, Department of Health Behavior and Policy, One Capitol Square, 830 E Main Street, Suite 923, Richmond, VA 23298, United States of America.

E-mail address: [nicole.nicksic@vcuhealth.org](mailto:nicole.nicksic@vcuhealth.org) (N.E. Nicksic).

<https://doi.org/10.1016/j.ypmed.2019.02.006>

Received 7 July 2018; Received in revised form 25 January 2019; Accepted 7 February 2019

Available online 16 February 2019

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specified product one year later, yet the models controlled for socio-demographic factors only and also did not assess other outcomes (Pierce et al., 2018). The current study extends this sparse evidence base by investigating whether susceptibility to e-cigarette use among adolescents naïve to tobacco and substance use is correlated with ever use or initiation, and past 30-day use of e-cigarettes and cigarettes, and initiation of marijuana and alcohol use one year later. Importantly, ever use of tobacco and other substances, academic performance, harm perceptions and sensation seeking, and exposure to tobacco use or to advertising, all previously identified as potential determinants of susceptibility (Bold et al., 2016; Case et al., 2017; Saddleson et al., 2015; Dai and Hao, 2016), are accounted for in the current study. Identifying the importance of e-cigarette susceptibility to the use of these and other tobacco products and substances will help guide more comprehensive tobacco and, more broadly, substance use prevention policies.

## 2. Methods

Two waves of data from the Population Assessment of Tobacco and Health (PATH) Study, a nationally representative, longitudinal cohort of over 45,000 adults and youth were analyzed. PATH used a four-staged stratified area probability sample design to contact potential participants at over 150,000 addresses. Respondents completed a household screener, where up to two adults and two children (12–17 years) were invited to participate. The sample was weighted for nonresponse in order to generalize to the US non-institutionalized, civilian youth population, and the adjusted response rate was 78.4% (Hyland et al., 2017). A parent or guardian provided consent for their participating child and completed a parent interview on socio-demographics, parent tobacco use, and their child's health. Further details on the PATH study design and methodology are published elsewhere (Hyland et al., 2017). The Virginia Commonwealth University Institutional Review Board approved the current study as exempt from further review (ID HM20009330).

### 2.1. Study population

Data were collected from 13,651 youth and a parent or guardian of 13,588 youth at Wave 1 (September 2013–December 2014), and 11,996 participants one year later (Wave 2, October 2014–October 2015). By Wave 2, 2239 youth reached 18 years of age and transitioned into the adult cohort. After exclusion of these “aged up” youth and loss to follow-up, 10,081 youth completed Waves 1 and 2 of the youth survey. In order to obtain a sample of naïve adolescents, youth who had ever used an e-cigarette ( $n = 846$ ), cigarette ( $n = 1023$ ), alcohol ( $n = 3297$ ), marijuana ( $n = 1022$ ), and other tobacco (traditional cigar, filtered cigar, cigarillo, pipe, hookah, snus, smokeless, dissolvable, bidis, and/or kreteks;  $n = 996$ ) in Wave 1 were excluded from the sample ( $n = 3869$  users of at least one of these products and  $n = 86$  had missing responses for at least one product). Additionally, youth who had never seen or heard of e-cigarettes in Wave 1 ( $n = 1451$ ) were excluded. The final sample consisted of 5156 participants, representing a population of 10,442,792 US youth 12 to 17 years old who had never used tobacco products, alcohol, or marijuana at Wave 1.

### 2.2. Susceptibility to E-cigarettes at Wave 1

E-cigarette susceptibility was adapted from three established items of susceptibility to cigarettes (Pierce et al., 1996; Strong et al., 2015; Pierce et al., 2005, 2017, 2018). Youth who had never used an e-cigarette were first asked, “Have you ever been curious about using e-cigarettes?” and had the response options of “Not at all curious,” “A little curious,” “Somewhat curious,” or “Very curious.” The other two questions, “Do you think that you will try an e-cigarette soon?” and “If one of your best friends were to offer you an e-cigarette, would you use it?” had the response options of “Definitely not,” “Probably not,”

“Probably yes,” or “Definitely yes.” Non-susceptible youth answered “Not at all curious” to the first question and “Definitely not” to the other two questions. Any other response combination is considered lacking a firm commitment to not use e-cigarettes in the future and these youth were categorized as susceptible (Pierce et al., 1996; Strong et al., 2015; Pierce et al., 2005, 2017, 2018).

### 2.3. Other risk factors at wave 1

#### 2.3.1. Cigarette susceptibility

Youth who had never smoked cigarettes were asked three questions based on established susceptibility measures: “Have you ever been curious about smoking a cigarette?”, “Do you think you will smoke in the next year?”, and “If one of your best friends were to offer you a cigarette, would you smoke it?” (Pierce et al., 1996; Strong et al., 2015; Pierce et al., 2005). Cigarette susceptibility was coded the same as e-cigarette susceptibility, where responding with “Not at all curious” and “Definitely not” to all three questions meant youth were non-susceptible to cigarette use.

#### 2.3.2. Academic performance

Youth grade performance was measured by asking parents “How would you describe how your child has performed at school in the past 12 months? Would you say your child's grades are...” The derived response scale ranged from (Jamal et al., 2017) “Mostly A's” to (Strong et al., 2015) “Mostly F's” and were dichotomized as “Mostly B's and higher” and “B/C or lower” (McCabe et al., 2017).

#### 2.3.3. Harm perceptions and sensation seeking

Perceived relative e-cigarette harm was measured by asking “Is using e-cigarettes less harmful, about the same, or more harmful than smoking cigarettes?”. Response options were dichotomized as ‘about the same/more harmful’ and ‘less harmful’. Youth were asked their level of agreement ((Jamal et al., 2017) ‘Strongly disagree’ to (Watkins et al., 2018) ‘Strongly agree’) in the following Sensation Seeking Scale questions: “I like to do frightening things;” “I like new and exciting experiences, even if I have to break the rules;” “I prefer friends who are exciting and unpredictable.” Responses were summed and averaged to provide a mean sensation seeking score (Case et al., 2017).

#### 2.3.4. Exposure to tobacco use or to advertising

Family tobacco use was evaluated by selecting that anyone who lives with you now smokes or uses cigarettes, smokeless tobacco, cigars, cigarillos, filtered cigars, or any other form of tobacco (no/any). Youth were exposed to secondhand smoke if they had been around others who were smoking, including at home, in a car, at school, or outdoors, for at least a total of an hour during the past seven days (no/yes). Favorite tobacco advertisement was measured if a youth selected a tobacco brand as their favorite or that they did not have a favorite tobacco advertisement (no/yes). Youth were shown five randomized, recently used e-cigarette advertisements (two TV and three print) and were asked “In the past 12 months, have you seen this advertisement before this study?” for each advertisement (aided recall). Youth were considered to have recalled e-cigarette advertisements if they had recalled any of the five advertisements (Pierce et al., 2018).

### 2.4. Sociodemographic characteristics

Wave 1 sociodemographic descriptors of youth who had never used e-cigarettes included sex, age (12 to 14 years and 15 to 17 years), race/ethnicity (White, African American, Hispanic, other), and parent education (high school/GED or less, some college, Bachelor's degree or higher).

## 2.5. Tobacco and other substance use behaviors at Wave 2

Tobacco and other substance use outcomes were measured at Wave 2. Initiation of e-cigarettes, cigarettes, marijuana, and alcohol was measured as never users in Wave 1 who had ever used the specified product within the year between surveys. Cigarette ever use, was measured by ever smoking a cigarette, even 1 or 2 puffs (no/yes); marijuana ever use by “Have you ever used marijuana, hash, THC, grass, pot, or weed?” (no/yes); and alcohol ever use by “Have you ever used alcohol at all, including sips of someone's drink or your own drink?” (no/yes). Past 30-day use of e-cigarettes and cigarettes was defined as youth had used these products in the 30 days prior to Wave 2.

## 2.6. Statistical analysis

Analysis was performed with Stata 12.0 (College Station, Texas, US). Missing data were imputed for perceived e-cigarette harm (24.7% missing), e-cigarette susceptibility (16.0%), favorite tobacco advertisement (12.3%), secondhand smoke exposure (3.5%), sensation seeking (2.4%), family uses tobacco (1.2%), grades (0.9%), parent education (0.6%), cigarette susceptibility (0.2%), and recall of e-cigarette advertisements (0.1%), using multiple imputation methods (10 imputations) (Allison, 2002). Data were complete for sex, age, and race/ethnicity. The individual items for e-cigarette and cigarette susceptibility and sensation seeking behavior were imputed before the measures were operationalized. Analysis was fit to the 10 imputed data sets using the “mi” command. Bivariate and adjusted associations between susceptibility to e-cigarettes in Wave 1 (predictor) and Wave 2 initiation of e-cigarettes, cigarettes, marijuana, and alcohol, as well as past 30-day use of e-cigarettes and cigarettes (outcomes) were tested using weighted logistic regressions. Adjusted models controlled for cigarette susceptibility, academic performance, harm perceptions and sensation seeking, exposure to tobacco use or to advertising, and sociodemographic characteristics. The sample size for each of regression model was determined by the completeness of Wave 2 tobacco and substance use outcomes. Longitudinal Wave 2 survey weights to adjust for nonresponse were used in analysis using the “svy” command.

## 3. Results

### 3.1. Sample characteristics

Among PATH youth aged 12–17 years old who had never used tobacco products, marijuana, or alcohol in Wave 1 and completed both Waves 1 and 2, 30.4% were 15 to 17 years, 46.8% female, 53.0% Non-Hispanic White, and 35.9% had parents with a high school degree/GED or less (Table 1). Nearly half of the sample (47.0%) perceived e-cigarettes to be less harmful than cigarettes. Nearly a third had been exposed to secondhand smoke (32.3%), had a family member who lived with them who used tobacco (30.1%), and had recalled e-cigarette advertisements (29.5%). Among never users in Wave 1, 13.2% initiated alcohol use, 5.1% e-cigarettes, 4.4% marijuana, and 2.1% began using cigarettes in Wave 2.

### 3.2. Associations between Wave 1 susceptibility to E-cigarettes and Wave 2 tobacco and other substance use

Among youth who had never used tobacco products, marijuana, or alcohol in Wave 1, being susceptible to e-cigarettes in Wave 1 was significantly associated with increased odds of initiating use of e-cigarettes (adjusted Odds Ratio [aOR], 2.22; 95% CI, 1.55–3.18), marijuana (aOR, 1.66; 95% CI, 1.12–2.46), and alcohol (aOR 1.61; 95% CI, 1.26–2.06) in Wave 2, after adjusting for other risk factors and sociodemographic characteristics. E-cigarette susceptibility was also significantly associated with past 30-day e-cigarette use (aOR, 3.64; 95%

CI, 1.93–6.89). Additionally, e-cigarette susceptibility was associated with cigarette initiation (unadjusted OR, 4.18; 95% CI 2.80–6.24) and past 30 day use (unadjusted OR, 4.86; 95% CI, 2.66–8.86) univariately (Table 1), but not after adjusting for other risk variables and socio-demographics (Table 2).

### 3.3. Associations between other risk variables, sociodemographics, and Wave 2 tobacco and substance use

Cigarette susceptibility, academic performance, harm perceptions and sensation seeking, and exposure to tobacco use or to advertising variables were all statistically significantly associated with susceptibility to e-cigarette use in Wave 1 (unadjusted OR, 1.40–17.96; Table 1). After adjustment, Wave 1 cigarette susceptibility was associated with initiation of e-cigarettes (aOR, 1.83; 95% CI, 1.28–2.63), cigarettes (aOR, 3.36; 95% CI, 1.95–5.82), marijuana (aOR, 1.99; 95% CI, 1.33–2.98), and alcohol (aOR, 1.28; 95% CI, 1.01–1.64) and past 30 day cigarette (aOR, 2.83; 95% CI, 1.34–5.97) use. Youth with higher mean sensation seeking scores had increased odds of initiation of e-cigarettes (aOR, 1.37; 95% CI, 1.15–1.63), marijuana (aOR, 1.48; 95% CI, 1.24–1.78), and alcohol (aOR, 1.35; 95% CI, 1.22–1.50) and past 30 day e-cigarette (aOR, 1.44; 95% CI, 1.08–1.93) and cigarette (aOR, 1.55; 95% CI, 1.13–2.13) use. Recall of e-cigarette advertisements was associated with initiating e-cigarette (aOR, 1.35; 95% CI, 1.01–1.80), marijuana (aOR, 1.36; 95% CI, 1.02–1.82), and alcohol (aOR, 1.27; 95% CI, 1.05–1.54) use and past 30 day cigarette use (aOR, 1.82; 95% CI, 1.01–3.32).

Being 15–17 years old, female, African American, or Hispanic was statistically significantly associated with susceptibility to e-cigarettes in Wave 1 (unadjusted OR 0.86–1.45; Table 1). Females had higher odds of initiating alcohol (aOR, 1.82; 95% CI, 1.51–2.19) and past 30 day cigarette (aOR, 1.90; 95% CI, 1.03–3.48) use compared to males (Table 2). Compared to White youth, African American and Hispanic youth had decreased odds of initiating e-cigarette use and past 30 day e-cigarette and cigarette use (aOR, 0.20–0.70). Hispanic youth had decreased odds of initiating cigarette use (aOR, 0.48; 95% CI, 0.28–0.83), and African American youth had decreased odds of initiating alcohol use (aOR, 0.62; 95% CI, 0.46–0.83). Youth with highly educated parents (Bachelor's degree or higher) had decreased odds of cigarette initiation and past 30-day use and marijuana initiation (aOR, 0.16–0.62).

## 4. Discussion

The findings from this study indicate the importance of studying e-cigarette susceptible youth, as they are at risk for future e-cigarette use, as well as use of other tobacco products and substances. Among youth who had never used tobacco, marijuana or alcohol in Wave 1, youth who were susceptible to e-cigarette use were significantly more likely by Wave 2 to have tried e-cigarettes, cigarettes, alcohol or marijuana compared to youth who were not susceptible. After controlling for established risk factors and sociodemographic variables, e-cigarette susceptibility was a strong predictor of initiation of e-cigarettes, marijuana, and alcohol and past 30-day use of e-cigarettes. When controlling for both cigarette and e-cigarette susceptibility, cigarette susceptibility predicted cigarette initiation and past 30-day use, while e-cigarette susceptibility was not statistically significant. Further, cigarette susceptibility also predicted initiation of e-cigarettes, marijuana, and alcohol, yet did not predict past 30-day e-cigarette use. These results align with previous findings on susceptibility and progression to use, where susceptibility to a specific product predicts initiation to that product one year later (Pierce et al., 2018). However, we also determined that adjusted models including susceptibility to either e-cigarettes or cigarettes predicted all Wave 2 outcomes. These findings indicate that susceptibility is successful in predicting specific product use when controlled together, yet individual susceptibility measures could predict use across substances. Thus, susceptibility to either e-

**Table 1**

Weighted proportions and univariate associations of Wave 2 outcomes and imputed Wave 1 predictors by e-cigarette non-susceptible and susceptible youth in the PATH Study (n = 5156; N = 10,442,792).

	Total n <sup>a</sup>	Total % (95% CI)	Non-susceptible to E-cigarette use % (95% CI)	Susceptible to E-cigarette use <sup>b</sup> % (95% CI)	Unadjusted OR (95% CI)
<b>Wave 1 variables</b>					
Susceptible to cigarettes	1200	22.7 (21.5–23.9)	10.1 (9.1–11.1)	66.9 (64.0–69.8)	17.96 (15.16–21.28)
Grades B/C or lower	1468	27.1 (25.8–28.3)	24.9 (23.5–26.3)	34.5 (31.6–37.4)	1.58 (1.36–1.84)
Less perceived harm E-cigarette	2896	47.0 (45.5–48.5)	42.2 (40.5–44.0)	63.6 (60.5–66.6)	2.39 (2.05–2.78)
Family uses tobacco	1596	30.1 (28.7–31.4)	28.5 (27.0–29.9)	35.7 (32.7–38.6)	1.40 (1.20–1.62)
Secondhand smoke exposure	1683	32.3 (30.9–33.6)	28.9 (27.4–30.4)	43.9 (40.8–47.0)	1.92 (1.66–2.22)
Sensation seeking, mean (SE) <sup>c</sup>	2.38 (0.01)	2.37 (0.01)	2.27 (0.01)	2.72 (0.03)	1.83 (1.69–1.99)
Favorite tobacco ad	289	5.6 (4.9–6.3)	4.6 (3.9–5.3)	8.9 (7.1–10.8)	2.02 (1.54–2.65)
Recall of E-cigarette ads	1559	29.5 (28.2–30.8)	27.2 (25.7–28.6)	37.8 (34.8–40.8)	1.63 (1.41–1.89)
Female	2423	46.8 (45.4–48.3)	47.7 (46.1–49.4)	43.8 (40.8–46.9)	0.86 (0.74–0.98)
15 to 17 years old	1559	30.4 (29.1–31.8)	29.3 (27.8–30.8)	34.4 (31.5–37.3)	1.26 (1.09–1.47)
<b>Race/ethnicity</b>					
White	2417	53.0 (51.6–54.5)	54.2 (52.6–55.9)	48.7 (45.6–51.8)	Ref
African American	773	15.1 (14.1–16.2)	14.7 (13.5–15.9)	16.7 (14.4–19.0)	1.27 (1.03–1.55)
Hispanic	1494	22.4 (21.3–23.5)	21.0 (19.7–22.2)	27.3 (24.8–29.8)	1.45 (1.24–1.70)
Other	472	9.5 (8.5–10.4)	10.1 (9.0–11.2)	7.3 (5.6–8.9)	0.81 (0.61–1.07)
<b>Parent education</b>					
High school/GED or less	2037	35.9 (34.5–37.3)	35.1 (33.6–36.7)	38.6 (35.7–41.6)	Ref
Some college	1636	31.5 (30.2–32.9)	32.0 (30.4–33.5)	29.9 (27.1–32.7)	0.85 (0.72–1.01)
Bachelor's or higher	1483	32.6 (31.2–34.0)	32.9 (31.3–34.5)	31.5 (28.5–34.4)	0.87 (0.74–1.03)
<b>Wave 2 outcomes</b>					
Initiate E-cigarette use	259	5.1 (4.4–5.7)	3.1 (2.6–3.7)	11.9 (9.8–13.9)	4.20 (3.20–5.50)
Past 30 day E-cigarette use	62	1.2 (0.9–1.5)	0.6 (0.4–0.9)	3.3 (2.2–4.4)	5.53 (3.24–9.41)
Initiate cigarette use	110	2.1 (1.7–2.5)	1.3 (0.9–1.6)	5.0 (3.7–6.4)	4.18 (2.80–6.24)
Past 30 day cigarette use	48	0.9 (0.7–1.2)	0.5 (0.3–0.7)	2.4 (1.5–3.3)	4.86 (2.66–8.86)
Initiate marijuana use	236	4.4 (3.8–4.9)	2.9 (2.4–3.5)	9.4 (7.6–11.1)	3.42 (2.58–4.54)
Initiate alcohol use	660	13.2 (12.2–14.2)	10.9 (9.8–11.9)	21.4 (18.8–23.9)	2.23 (1.85–2.68)

<sup>a</sup> n represents the imputed, unweighted sample size for Wave 1 variables. Wave 2 variable total sample sizes (n) were not imputed and unweighted.

<sup>b</sup> The imputed, unweighted sample size (n) of e-cigarette susceptible youth was 1175.

<sup>c</sup> Sensation seeking is a continuous mean score with a range of 1–5. Under the total column, the mean (SE) is imputed, yet unweighted.

**Table 2**

Weighted associations of imputed Wave 1 predictors and Wave 2 outcomes among US youth in the PATH Study (n = 5156; N = 10,442,792).

Wave 1 variables	Wave 2 outcomes					
	Initiate E-cigarette use aOR (95% CI)	Past 30 day E-cigarette use aOR (95% CI)	Initiate cigarette use aOR (95% CI)	Past 30 day cigarette use aOR (95% CI)	Initiate marijuana use aOR (95% CI)	Initiate alcohol use aOR (95% CI)
Susceptible to E-cigarettes	2.22 (1.55–3.18)	3.64 (1.93–6.89)	1.62 (0.95–2.78)	1.91 (0.91–3.98)	1.66 (1.12–2.46)	1.61 (1.26–2.06)
Susceptible to cigarettes	1.83 (1.28–2.63)	1.27 (0.63–2.58)	3.36 (1.95–5.82)	2.83 (1.34–5.97)	1.99 (1.33–2.98)	1.28 (1.01–1.64)
Grades B/C or lower	1.50 (1.11–2.04)	1.41 (0.80–2.47)	1.98 (1.28–3.07)	2.11 (1.14–3.90)	1.74 (1.29–2.35)	1.05 (0.85–1.30)
Less perceived harm of E-cigarettes	1.57 (1.17–2.11)	1.36 (0.79–2.32)	0.96 (0.63–1.47)	0.72 (0.38–1.36)	1.08 (0.80–1.46)	1.10 (0.91–1.32)
Family uses tobacco	1.49 (1.08–2.06)	1.09 (0.56–2.11)	0.98 (0.63–1.51)	0.94 (0.46–1.93)	1.61 (1.12–2.32)	1.17 (0.95–1.46)
Secondhand smoke exposure	0.99 (0.72–1.36)	1.39 (0.75–2.59)	1.67 (1.08–2.58)	2.28 (1.11–4.71)	1.07 (0.76–1.49)	1.09 (0.88–1.35)
Sensation seeking	1.37 (1.15–1.63)	1.44 (1.08–1.93)	1.23 (0.93–1.63)	1.55 (1.13–2.13)	1.48 (1.24–1.78)	1.35 (1.22–1.50)
Favorite tobacco ad	1.17 (0.68–2.00)	1.32 (0.52–3.34)	1.26 (0.62–2.58)	1.74 (0.65–4.66)	1.47 (0.87–2.48)	1.33 (0.92–1.95)
Recall of E-cigarette ad	1.35 (1.01–1.80)	1.00 (0.57–1.74)	1.40 (0.92–2.13)	1.82 (1.01–3.32)	1.36 (1.02–1.82)	1.27 (1.05–1.54)
Female	1.11 (0.84–1.47)	1.15 (0.68–1.94)	1.49 (0.98–2.25)	1.90 (1.03–3.48)	1.31 (0.99–1.74)	1.82 (1.51–2.19)
15 to 17 years old	1.26 (0.95–1.68)	1.06 (0.61–1.84)	1.18 (0.76–1.83)	1.65 (0.87–3.11)	1.48 (1.10–1.99)	1.60 (1.32–1.92)
<b>Race/ethnicity</b>						
White	Ref	Ref	Ref	Ref	Ref	Ref
African American	0.35 (0.21–0.59)	0.20 (0.07–0.59)	0.56 (0.30–1.03)	0.34 (0.13–0.88)	1.37 (0.92–2.03)	0.62 (0.46–0.83)
Hispanic	0.70 (0.49–0.99)	0.42 (0.20–0.86)	0.48 (0.28–0.83)	0.25 (0.11–0.61)	1.08 (0.75–1.57)	0.86 (0.68–1.08)
Other	0.71 (0.41–1.22)	0.37 (0.13–1.08)	0.41 (0.16–1.07)	0.16 (0.04–0.72)	0.97 (0.57–1.64)	0.75 (0.53–1.06)
<b>Parent education</b>						
High school/GED or less	Ref	Ref	Ref	Ref	Ref	Ref
Some college	0.99 (0.71–1.36)	0.60 (0.31–1.17)	0.73 (0.47–1.15)	0.73 (0.37–1.44)	0.74 (0.54–1.02)	1.16 (0.93–1.44)
Bachelor's or higher	0.67 (0.45–1.01)	0.53 (0.25–1.17)	0.26 (0.13–0.53)	0.16 (0.05–0.55)	0.62 (0.40–0.96)	1.27 (0.99–1.62)

aOR = adjusted Odds Ratio.

cigarettes or cigarettes could be a broader risk factor when measured on their own. In order to discriminate among susceptible youth within tobacco products, both measures would be needed. Importantly, comparison of susceptibility to e-cigarettes and cigarettes can inform

policy-makers on specific groups of youth to target.

The current study also suggests that other risk factors could predict e-cigarette use over time. Lower grades, lower perceived e-cigarette harm, family use of tobacco, and higher mean sensation seeking scores

predicted e-cigarette initiation. Notably, recall of e-cigarette advertising in Wave 1 predicted Wave 2 e-cigarette initiation in addition to past 30-day cigarette use and initiation of marijuana and alcohol. This is significant as current e-cigarette advertising restrictions are minimal (U.S. Food and Drug Administration, 2018), and this evidence suggests prohibiting advertisements could be advantageous to tobacco control efforts as well as marijuana use and underage drinking. Further, lower grades and secondhand smoke exposure predicted cigarette initiation and use. Higher mean sensation seeking scores predicted initiation of marijuana and alcohol, and family use of tobacco and lower grades predicted marijuana initiation. As previous studies on e-cigarette susceptibility have not controlled for these other risk factors, these findings are a novel contribution to the evidence base on e-cigarette susceptibility and substance use among youth. Other risk factors should be considered in future e-cigarette use behaviors research, as well as for targeting specific youth in tobacco and substance prevention programs.

Several sociodemographic differences among Wave 2 outcomes are noteworthy. Females had a lower likelihood of susceptibility to e-cigarettes than males, yet had a greater likelihood of past 30-day use of cigarettes and initiating alcohol but were not different in initiation or current use of e-cigarettes or initiation of cigarettes and marijuana. While prevalence of cigarette smoking has traditionally been higher among males (Higgins et al., 2015), recent National Youth Tobacco Survey (NYTS) data has shown cigarette smoking among females has become equivalent to males. In 2017, there was a 0.1 percentage point difference between male and female high school students, and females had a higher prevalence than males (0.2 percentage point difference) among middle school students (Wang et al., 2018). According to NYTS data, this current shift in prevalence of cigarette smoking may be due to the increasing popularity of e-cigarettes among males (Wang et al., 2018), although PATH data has not shown this difference. Cigarette, e-cigarette, and alcohol use was higher among White youth, which aligns with previous findings on cigarettes and e-cigarette ever use and race in Wave 1 (Trinidad et al., 2017). Additionally, youth with highly educated parents may be less likely to use cigarettes or marijuana but were not different in initiation of e-cigarettes or alcohol. These findings could support culturally tailored tobacco and substance use prevention efforts.

In summary, e-cigarette susceptibility appears to be a predictor not only future e-cigarette use but, importantly, also of marijuana and alcohol, which has not been previously documented to our knowledge. E-cigarette and cigarette susceptibility may be specific measures when observed together, yet both measures can predict use across all substances when analyzed individually. Further study is needed to determine changes among susceptible youth over longer periods, and to determine if susceptible youth who initiate using tobacco and other substances remain experimental users or become established users. Additionally, further study of cigarette and e-cigarette susceptibility together and independently will provide more information on the utility of product-specific susceptibility measures in predicting use of tobacco and other substances. Further, as the class of e-cigarette products evolves over time, additional research on the changing role of susceptibility in predicting future use will be required.

#### 4.1. Limitations

All data were self-reported, thus there may be measurement error in tobacco and other substance use behaviors. Not all potential risk factors were included in this study, though many of the established risk factors of tobacco and substance use behaviors were included in our regression analyses (Bold et al., 2016; Case et al., 2017; Saddleson et al., 2015; Dai and Hao, 2016). Additionally, while the e-cigarette susceptibility measure was modeled after validated cigarette susceptibility measures (Pierce et al., 1996, 2005), susceptibility has not yet been validated for e-cigarette use. Susceptibility to marijuana or alcohol use is not measured in PATH and could not be included as a baseline confounder. As

youth can remain susceptible for several years (Pierce et al., 1996; Messer and Pierce, 2010; Strong et al., 2015), the low level of cigarette initiation found within this short follow-up window does not preclude initiation from occurring and being observed in later waves. Receptivity to advertisements could be an important risk factor for tobacco and substance initiation and should be included in future studies, but sensitivity analyses testing e-cigarette and cigarette advertisement receptivity in adjusted associations were not significant, likely due to limited power. Our findings represent associations between Wave 1 risk factors and Wave 2 outcomes, but our results should not be interpreted as causal. While our analysis imputed Wave 1 variables that were missing, our main results were not sensitive to using complete case analysis.

## 5. Conclusion

E-cigarettes are the most commonly used tobacco product among youth. In addition to their own potential for harms, e-cigarette use is associated with initiation of conventional cigarette smoking. However, limited research exists whether susceptibility to e-cigarette use is a risk factor for future tobacco and other substance use initiation. This study is among the first to investigate associations between e-cigarette susceptibility and e-cigarette, cigarette, marijuana, and alcohol use one year later among a nationally representative cohort of youth. We found that, among youth naïve to use of tobacco products, alcohol, and marijuana, e-cigarette susceptibility predicts initiation of e-cigarettes, marijuana, and alcohol, as well as past 30-day e-cigarettes one year later after controlling for other established risk factors. Cigarette susceptibility, yet not e-cigarette susceptibility, was associated with initiation and past 30 day use of cigarettes. When assessed simultaneously, these susceptibility measures predict product-specific use, yet when measured individually, these measures could predict use across tobacco products and other substances. The evidence suggests that prevention policies should target youth susceptible to e-cigarettes reduce the current trends in using these products and such efforts may potentially reduce the use of tobacco and other substances as well. Finally, tobacco prevention programming targeting youth susceptible to e-cigarette use may consider adding other substance use prevention to such campaigns and, importantly, evaluations of the effectiveness of efforts to intervene among youth susceptible to e-cigarettes should consider measuring the use of other tobacco products, alcohol, and marijuana as additional outcomes.

## Conflict of interest

None declared.

## Funding

NEN is funded by the National Institute on Drug Abuse of the National Institutes of Health and the Center for Tobacco Products of the U.S. Food and Drug Administration (P50DA036105) and the National Cancer Institute of the National Institutes of Health (T32CA093423). AJB is funded by the National Cancer Institute of the National Institutes of Health (5UG1CA189869), the National Institute on Drug Abuse of the National Institutes of Health (R03DA043005; U54DA0361905), and the Virginia Foundation for Healthy Youth #8521068. This article is solely the responsibility of the author and does not necessarily represent the official views of the National Institutes of Health or the Food and Drug Administration.

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