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# Measurement and predictive value of susceptibility to cigarettes, e-cigarettes, cigars, and hookah among Texas adolescents

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A B S T R A C T

Susceptibility to cigarette smoking, defined as the lack of a firm commitment not to smoke in the future, begins in childhood and is a phase in the transition from never to ever use of cigarettes. While a consistent and validated predictor of cigarette use, little research has assessed whether the susceptibility construct applies equally well across other tobacco products. Baseline data were collected in 2014–2015 from a representative sample of ($n$ = 2844) middle and high school students in five counties surrounding the four largest cities in Texas, (49% female and mean age 13.13 years, with subsequent waves at 6, 12, and 18 months. Confirmatory factor analysis examined the appropriateness of a three-item susceptibility measure (product-specific curiosity, intention to use, and peer influence) across product types and ethnic groups (Hispanic versus non-Hispanic). Logistic regression examined whether product specific susceptibility at baseline predicted future product initiation. At baseline, 11.5%, 17.0%, 17.4% and 29.4%, of adolescent never users were susceptible to cigars, cigarettes, hookah and e-cigarettes, respectively; significantly more Hispanic than non-Hispanic adolescents were susceptible to e-cigarettes (32.4% versus 26%, $p < 0.01$) and cigarettes (19.9% versus 13.9%, $p < 0.05$). Product-specific items were significantly and consistently associated with the respective underlying susceptibility product construct and across ethnic groups ($p < 0.001$ for all). Susceptibility to e-cigarettes (AOR = 2.28–6.64) or any combustible product (cigarettes, hookah, cigars; AOR = 3.38–5.20) significantly predicted subsequent ever use. This study confirms the appropriateness of the susceptibility construct across four tobacco product types and ethnic groups, and the utility of susceptibility in predicting future product use among adolescents.

## 1. Introduction

Use of conventional tobacco products, like cigarettes and cigars, has decreased in recent years among adolescents, while use of tobacco products, like e-cigarettes and hookah, continues to increase (Singh et al., 2016). These trends and the growing popularity of specific products call for identifying risk factors that predict product use initiation. Numerous studies have demonstrated susceptibility to cigarettes among never smoking adolescents is associated with increased risk of experimentation with cigarettes and becoming an established smoker (Jackson, 1998; Jackson & Dickinson, 2004; Nodora et al., 2014; Pierce, Choi, Gilpin, Farkas, & Merritt, 1996; Pierce, Distefan, Kaplan, & Gilpin, 2005; Spelman et al., 2009; Strong et al., 2015; Unger, Johnson, Stoddard, Nezami, & Chou, 1997). Limited research suggests that susceptibility to e-cigarettes or hookah independently predicts future e-cigarette (Bold, Kong, Cavallo, Camenga, & Krishnan-Sarin, 2017) or hookah use (Lipkus, Reboussin, Wolfson, & Sutfin, 2015), respectively, and that susceptibility to cigarettes predicts future e-cigarette and cigar use (Cole, Kennedy, Chaurasia, & Leatherdale, 2017). Still, few studies have examined product-specific susceptibility measures in predicting future use of products other than cigarettes.

Susceptibility, which reflects the lack of a firm commitment not to use tobacco products in the future, is a critical construct, predictive of tobacco use and amenable to intervention. Research examining the initial susceptibility construct based on behavioral intentions, peer influence, and self-efficacy (Pierce et al., 1996) demonstrated that comprehensive community anti-smoking media programs, are effective in altering and suppressing adolescents' susceptibility to smoking (Meshack et al., 2004). A revised measure of the susceptibility construct, which incorporated curiosity with behavioral intentions and peer influence, demonstrated little loss in internal consistency, but a reduction in predictive validity and accuracy (Pierce et al., 2005). To date, a few studies have assessed whether the original susceptibility to cigarettes construct (Pierce et al., 1996) also can be adapted to measure susceptibility to other products, like e-cigarettes, hookah, and cigars (e.g., Bold et al., 2017; Lechner et al., 2018), and none have examined the susceptibility construct that includes curiosity. Yet, recent survey data suggest that the most common reason for adolescents to try e-cigarettes is out of curiosity (Kong, Morean, Cavallo, Camenga, & Krishnan-Sarin, 2015; Patrick et al., 2016). Thus, utilizing a susceptibility construct that includes curiosity might be particularly useful to our understanding of susceptibility to non-cigarette tobacco products.

Additionally, no studies have assessed whether the susceptibility construct (Pierce et al., 2005) functions equally across ethnic groups.

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**Table 1**
Demographics and susceptibility to e-cigarettes and combustible tobacco products among Hispanic and non-Hispanic never users at baseline, TATAMS ($n$ = 2844; $N$ = 318,097).

| Variable | Hispanic | Non-Hispanic | Total |
|---|---|---|---|
| | % (95% CI) | % (95% CI) | % (95% CI) |
| **Sex** | | | |
| Female | 47.7 (41.1–54.5) | 50.3 (45.1–55.5) | 49.0 (43.7–54.3) |
| Male | 52.3 (45.5–58.9) | 49.7 (44.5–54.9) | 51.0 (45.7–56.3) |
| **Grade** | | | |
| 6 | 39.8 (28.4–52.5) | 36.6 (23.6–52.0) | 38.3 (26.9–51.1) |
| 8 | 35.3 (24.4–48.0) | 34.4 (20.2–51.9) | 34.9 (23.7–47.9) |
| 10 | 24.9 (15.1–38.3) | 29.0 (18.4–42.7) | 26.9 (17.7–38.6) |
| **Age** (mean, SE) | 13.14 (0.19) | 13.12 (0.19) | 13.13 (0.17) |
| **Family SES** | | | ** |
| High | 15.8 (12.9–19.3) | 25.2 (18.7–33.0) | 20.3 (16.2–25.1) |
| Middle | 64.4 (61.2–67.5) | 61.6 (56.2–66.7) | 63.1 (60.2–65.9) |
| Low | 19.8 (16.8–23.2) | 13.2 (10.1–17.2) | 16.6 (14.1–19.6) |
| **Susceptibility to e-cigarettes items**[a] | | | |
| Have you ever been curious about smoking/using e-cigarettes? | 26.9 (23.5–30.7) | 22.2 (19.0–25.9) | 24.7 (21.9–27.7)* |
| Do you think you will use e-cigarettes in the next 12 months? | 10.5 (8.3–13.1) | 8.0 (6.1–10.4) | 9.3 (7.6–11.3) |
| If one of your close friends were to offer you an e-cigarette, would you use it? | 17.9 (15.1–21.1) | 13.0 (10.7–15.6) | 15.6 (13.6–17.7)* |
| **Susceptibility to e-cigarettes (derived)**[b] | 32.4 (28.7–36.3) | 26.0 (22.3–30.1) | 29.4 (26.2–32.7)** |
| **Susceptibility to cigars (large cigars, cigarillos, and little filtered cigars) items**[a] | | | |
| Have you ever been curious about smoking/using cigars? | 7.6 (5.6–10.3) | 7.0 (5.3–9.0) | 7.3 (6.0–8.8) |
| Do you think you will use cigars in the next 12 months? | 4.3 (2.8–6.5) | 3.2 (2.2–4.6) | 3.8 (2.8–5.0) |
| If one of your close friends were to offer you a cigar, would you use it? | 7.4 (5.0–10.8) | 4.5 (3.2–6.2) | 6.0 (4.6–7.8) |
| **Susceptibility to cigars (derived)**[b] | 12.8 (9.7–16.7) | 10.2 (7.9–13.0) | 11.5 (9.5–13.9) |
| **Susceptibility to hookah items**[a] | | | |
| Have you ever been curious about smoking/using hookah? | 14.7 (11.8–18.2) | 12.5 (9.6–16.2) | 13.7 (11.3–16.4) |
| Do you think you will use hookah in the next 12 months? | 6.9 (5.0–9.4) | 5.3 (3.6–7.6) | 6.1 (4.6–8.1) |
| If one of your close friends were to offer you hookah, would you use it? | 9.8 (7.6–12.6) | 7.8 (5.8–10.5) | 8.9 (7.2–10.9) |
| **Susceptibility to hookah (derived)**[b] | 18.8 (15.2–23.1) | 15.7 (12.1–20.2) | 17.4 (14.6–20.6) |
| **Susceptibility to cigarettes items**[a] | | | |
| Have you ever been curious about smoking/using cigarettes? | 13.3 (10.8–16.4) | 10.0 (8.3–12.1) | 11.8 (10.1–13.7)* |
| Do you think you will use cigarettes in the next 12 months? | 5.1 (3.4–7.4) | 3.9 (2.8–5.4) | 4.5 (3.5–5.8) |
| If one of your close friends were to offer you cigarettes, would you use it? | 8.4 (5.8–12.0) | 6.2 (4.6–8.2) | 7.3 (5.7–9.3) |
| **Susceptibility to cigarettes (derived)**[b] | 19.9 (15.6–25.0) | 13.9 (11.5–16.7) | 17.0 (14.4–20.0)* |
| **Susceptibility to any combustible tobacco product (derived)**[b] | 29.1 (24.5–34.1) | 22.9 (18.8–27.7) | 26.2 (22.7–29.9)* |

*Note*: CI = confidence interval, SE = standard error. All frequencies and means are weighted to account for complex survey design. Never users represent adolescents who have never used any of the four product types. $n$ represents the observed sample size, $N$ represents the weighted sample size. "Any combustible" includes cigarettes, cigars, and hookah. $^{*}p < 0.05$, $^{**}p < 0.01$ for Chi-square test of Hispanic versus non-Hispanic across categories of the item.

[a] For set of items, % (95% CI) represents the proportion of adolescents who said anything other than "not at all curious" to the first item and "definitely not" to the second two items.

[b] For items, % (95% CI) represents the proportion of adolescents classified as susceptible.

Hispanic adolescents who have never smoked report greater intentions to smoke cigarettes in the future compared to white peers (Bunnell et al., 2015) and greater curiosity about e-cigarettes (Margolis, Nguyen, Slavit, & King, 2016). In addition, Hispanic adolescents are more susceptible to cigarettes (Fulmer et al., 2015; Gritz et al., 2003), e-cigarettes (Singh et al., 2016; U.S. Department of Health and Human Services, 2016), and hookah (Trinidad et al., 2017), compared to non-Hispanic white adolescents. This is a concern because comparatively, Hispanics are the youngest ethnic group in the nation, with a large proportion of the Hispanic population (roughly a third) being under the age of 18 years (Patten, 2016), and Hispanic youth report a higher prevalence of e-cigarette use in middle school in the past 30 days compared to non-Hispanic youth of all races (Singh et al., 2016). Considering existing tobacco-related health disparities (Centers for Disease Control and Prevention, 2018) and the expected near doubling of the Hispanic population over the next 30 years (Krogstad, 2014), it is important to determine whether constructs predicting future use, like susceptibility, are applicable across ethnic groups. Such information can inform the development of culturally sensitive interventions and communication campaigns designed to reduce susceptibility and ultimately product use.

The goal of this study was to evaluate the utility of a three-item susceptibility construct adapted from Pierce et al. (2005), assessing curiosity, intention to use, and peer influence, in measuring susceptibility at baseline to four products (e-cigarettes, hookah, cigars, and cigarettes) and in predicting future initiation of these products among Hispanic and non-Hispanic adolescent never users in grades 6, 8, and 10 in Texas. We hypothesized the measurement of susceptibility would apply equally across products, and each product-specific susceptibility construct would predict future use of each product. We also hypothesized the measurement of susceptibility constructs for each product would apply equally across Hispanic and non-Hispanic subgroups, though prevalence of susceptibility to each product may be higher for Hispanic adolescents.

## 2. Methods

### 2.1. Study design and participants

The Texas Adolescent Tobacco and Marketing Surveillance system (TATAMS) is a rapid response surveillance system that follows three population-based cohorts of adolescents, to represent developmental changes in tobacco use behaviors. A complex probability design was used to recruit 3907 students ($n$) in 79 middle and high schools in 4 major metropolitan areas of Texas (Austin, San Antonio, Dallas-Ft. Worth, & Houston); when sampling weights are applied in statistical data analyses, results are representative of 461,069 ($N$) students who were enrolled in the 6th, 8th, and 10th grades in 1969 middle and high schools in these cities during the 2014–15 academic year. Further details about TATAMS' sampling methods and recruitment are described

elsewhere in Pérez et al. (2017). Active parental consent was obtained for all surveys, for all students.

Baseline data were collected during the 2014–2015 academic year from 3907 students via web-based surveys administered on tablets in the classroom, with three follow-up data collection periods occurring 6, 12, and 18 months after baseline via similarly formatted web-based surveys administered outside the classroom. At 6 months 64% were retained, at 12 months 70% were retained, and at 18 months 74% were retained. These retention rates are comparable to other cohorts nationwide with similar data collection schedules and incentive structures (Cantrell et al., 2018). Survey items were adapted from valid and reliable measures used for state and national tobacco surveillance, like the Population Assessment of Tobacco and Health (PATH) study (Hyland et al., 2017); cognitive interviewing among students, aged 11–18, assessed the reliability and content validity of all survey questions. The final survey included over 340 items assessing sociodemographic factors, tobacco use behaviors, cognitive and affective factors, and exposure to tobacco marketing. The median number of questions received by students was 137, with an average administration time of 45 minutes. The majority of students (58.1%) answered all items, and 92% of students answered 96% or more of the items (Delk, Harrell, Fakhouri, Muir, & Perry, 2017). Active consent from parents/guardians and assent from students were obtained for all data collection waves. TATAMS was approved by the University of Texas Health Science Center at Houston Institutional Review Board (HSC-SPH-13-0377).

The population for this study was limited to 2844 adolescents, or 72.8% of those enrolled at baseline, classified as never users of any product at baseline (i.e., a never user of e-cigarettes, cigars, hookah, and cigarettes) with complete data on all sociodemographic variables. Sampling weights were utilized, allowing the study population to be representative of 318,097 students enrolled in 6th, 8th, and 10th grades at baseline in these five Texas counties. As can been seen in Table 1, at baseline, sex was equally distributed (51% male), 38.3% of adolescents were in grade 6, and mean age was 13.13 (SE = 0.17). Most adolescents had a middle range family socioeconomic status (SES) (63.1%). Hispanic adolescents represented 52.4% of the study population. Of note, the Hispanic ($n$ = 1430) and non-Hispanic ($n$ = 1414) youth included in this analysis did not differ in terms of susceptibility to any of the four products examined to those excluded from the analysis due to missing covariates ($p < 0.05$ for all; data not shown).

### 2.2. Measures

#### 2.2.1. Susceptibility

Susceptibility to four product classes was examined among never users of any product: 1) e-cigarettes, 2) cigars (large cigars, cigarillos, and little filtered cigars), 3) hookah, and 4) cigarettes. Susceptibility to each product was assessed by three items asking, “Have you ever been curious about smoking/using [this product]?”, “Do you think you will use [this product] in the next 12 months?”, and “If one of your close friends were to offer you [this product], would you use it?” Response options included “Not at all curious,” “A little curious,” “Somewhat curious,” or “Very curious” for the first item and “Definitely not,” “Probably not,” “Probably yes,” or “Definitely yes” for the other two items. These items are adapted from a four item measure that has demonstrated good internal consistency in prior studies ($\alpha$ = 0.74) (Pierce et al., 2005) and is a strong predictor of future cigarette experimentation (Pierce et al., 1996, 2005).

Adolescents were categorized as non-susceptible to each individual item if they responded “Not at all curious” or “Definitely not,” with any other response categorized as susceptible. Derived susceptibility variables were created for each product, with individuals who were non-susceptible to all three items categorized as non-susceptible, those who were susceptible to one or more items categorized as susceptible, and those who were missing on any item labeled as missing. Susceptibility to any combustible product was derived based on susceptibility to cigars, hookah, and cigarettes, with individuals who were non-susceptible to all three products categorized as non-susceptible, those who were susceptible to one or more products categorized as susceptible, and those who were missing on susceptibility variables for all three products labeled as missing.

#### 2.2.2. Ever use

E-cigarette, cigar, hookah, and cigarette ever use were measured at 6, 12, and 18 months by one item each asking, “Have you ever smoked/used [this product], even one or two puffs?” with “Yes” responses classified as ever users of each product and “No” responses classified as never users. Ever use of any combustible product was measured based on whether adolescents were classified as ever users of any of the three combustible products (cigars, hookah, or cigarettes).

#### 2.2.3. Covariates

Covariates included sex (male or female), grade level (6, 8, or 10), age (range: 10–18 years), ethnicity, and family SES. Ethnicity was dichotomized as Hispanic versus non-Hispanic, which includes non-Hispanic adolescents of white, black, and other races. Family SES was measured by one item asking, “In terms of income, what best describes your family's standard of living in the home where you live most of the time?” with response options categorized as high (“very well off”), middle (“living comfortably”), and low (“just getting by,” “nearly poor,” and “poor”) (Gore, Aseltine Jr., & Colten, 1992; Romero, Cuéllar, & Roberts, 2000; Springer, Selwyn, & Kelder, 2006).

### 2.3. Analyses

The distribution of demographic and susceptibility measures across the total study population and by ethnicity were examined, and Chi-square tests assessed statistically significant differences between Hispanic and non-Hispanic adolescents across categories of these items.

Confirmatory factor analysis (CFA) assessed the fit of the three-item susceptibility construct for each of the four products among the total population and by ethnicity, using a robust weighted least squares approach with mean and variance adjusted estimation. CFA models were evaluated based on significance and size of model parameter estimates, and overall goodness-of-fit parameters, including the root mean square error of approximation (RMSEA, values < 0.06 indicate good fit), the comparative fit index (CFI, values > 0.95 indicate good fit), the Tucker-Lewis index (TLI, values > 0.95 indicate good fit), and the weighted root mean square residual (WRMR, values < 1.0 indicate good fit) (Hu & Bentler, 1999; Yu, 2002).

Following confirmation that each susceptibility construct fit appropriately across products and ethnicities, the predictive value of each derived susceptibility variable on future use of each product was examined at 6, 12, and 18 months among the total population and by ethnicity using Chi-square tests. Due to low numbers of ever users of combustible products, ever use of cigars, hookah, and cigarettes were combined as ever use of any combustible product, and logistic regression models examined the effect of susceptibility to e-cigarettes and any combustible product, separately, at baseline on ever use of these products at follow-up, adjusted for sex, age, family SES, and ethnicity.

All analyses were conducted using Stata 14.0 (College Station, TX) and Mplus Version 7 (Los Angeles, CA), utilizing complete case analysis of never users of any product at baseline. Analyses also incorporated sampling weights and considered clustering within school districts and stratification of schools based on proximity to point of sale tobacco outlets to account for complex design (Pérez et al., 2017).

## 3. Results

### 3.1. Descriptive statistics

At baseline (Table 1), the most commonly endorsed susceptibility

item across products was curiosity (24.7% for e-cigarettes, 13.7% for hookah, 11.8% for cigarettes, and 7.3% for cigars), while the least commonly endorsed item was intention to use (9.3% for e-cigarettes, 6.1% for hookah, 4.5% for cigarettes, and 3.8% for cigars). Based on derived susceptibility variables, 29.4% of adolescents were susceptible to e-cigarettes, 17.4% susceptible to hookah, 17.0% susceptible to cigarettes, and 11.5% susceptible to cigars; 26.2% were susceptible to any combustible product (hookah, cigarettes, or cigars).

Significant differences between Hispanic and non-Hispanic adolescents were observed for family SES, e-cigarette susceptibility, cigarette susceptibility, and susceptibility to any combustible product. For e-cigarette susceptibility, Hispanic adolescents, compared to non-Hispanic adolescents, endorsed curiosity (26.9% versus 22.2%) and peer influence (17.9% versus 13.0%) items more often and had a higher prevalence of being susceptible (32.4% versus 26.0%). For cigarette susceptibility, Hispanic adolescents, compared to non-Hispanic adolescents, endorsed curiosity more often (13.3% versus 10.0%) and had a higher prevalence of being susceptible (19.9% versus 13.9%). Hispanic adolescents had a higher prevalence of being susceptible to any combustible product (29.1%) compared to non-Hispanic adolescents (22.9%).

### 3.2. Confirmatory factor analysis

For the CFA among the total population and by Hispanic and non-Hispanic ethnicity (Table 2), parameter estimates for each item (curiosity, intention to use, and peer influence) were significant ($p < 0.001$) and displayed large loadings onto product specific susceptibility latent factors. Goodness-of-fit statistics suggested each susceptibility model was an appropriate fit to the data (RMSEA < 0.06, CFI > 0.95, TLI > 0.95, WRMR < 1.0 for all) among the total population and Hispanic and non-Hispanic groups specifically.

Among the total population, peer influence displayed the largest factor loading for e-cigarette susceptibility (β = 0.980, SE = 0.029), cigarette susceptibility (β = 0.904, SE = 0.055), and hookah susceptibility (β = 0.951, SE = 0.025), while intention to use displayed the largest factor loading for cigar susceptibility (β = 0.928, SE = 0.042). Curiosity displayed the lowest loading for all susceptibility constructs among the total population (β = 0.802, SE = 0.036 for e-cigarettes; β = 0.644, SE = 0.070 for cigarettes; β = 0.818, SE = 0.043 for hookah; β = 0.755, SE = 0.052 for cigars).

Results were consistent overall when examining each construct among Hispanic and non-Hispanic groups, with two exceptions. Among Hispanic adolescents only, intention to use displayed the largest factor loading (β = 0.888, SE = 0.090) for cigarette susceptibility, while peer influence displayed the largest factor loading (β = 0.931, SE = 0.070) for cigar susceptibility. Additional tests to examine differences in the measurement of each product specific construct when ethnicity is included in the model, ethnicity was significant to the measurement of susceptibility to e-cigarettes, but not to the measurement of susceptibility to other products (results not shown). However, the overall model fit, as well as factor loadings and the significance of each susceptibility item, remained consistent with e-cigarette models presented in Table 2.

### 3.3. Predictive validity

Among the total population, there were significant differences in ever use at 6, 12, and 18 months based on susceptibility status at baseline for e-cigarettes, cigarettes, hookah, and any combustible product (Fig. 1). Specifically, 6.3% of adolescents susceptible to e-cigarettes at baseline used e-cigarettes at 6 months, 11.3% at 12 months, and 13.8% at 18 months, versus 0.9%, 2.1%, and 4.6% of non-susceptible adolescents, respectively ($p < 0.05$ for all). Of those susceptible to cigarettes at baseline, 2.6% used cigarettes at 6 months, 6.6% at 12 months, and 9.4% at 18 months, versus 0.7%, 1.5%, and 2.8% of non-susceptible adolescents, respectively ($p < 0.05$ for all). Of those susceptible to hookah at baseline, 1.3% used hookah at 6 months, 2.7% at 12 months, and 3.8% at 18 months, versus 0%, 0.2%, and 0.4% of non-susceptible adolescents, respectively ($p < 0.05$ for all). Among adolescents susceptible to any combustible product at baseline, 3.7% used any combustible product at 6 months, 7.4% at 12 months, and 12.3% at 18 months, versus 0.7%, 1.7%, and 3.5% of non-susceptible adolescents, respectively ($p < 0.05$ for all). There were no significant differences in cigar ever use at any time point based on susceptibility to cigars at baseline.

When ethnicity was considered as a potential effect modifier of these relationships, few differences were noted. Among Hispanic adolescents, there were no significant differences in cigarette ever use at 6 months based on susceptibility to cigarettes at baseline; significant differences in ever use only emerged at 12 and 18 months ($p < 0.05$ for both). Among non-Hispanic adolescents, there were significant differences in cigar ever use at 12 and 18 months based on susceptibility to cigars at baseline, with 4.2% of susceptible adolescents using at

**Table 2**
Confirmatory factor analysis of susceptibility items for each product, total population and by ethnicity among never users at baseline, TATAMS ($n$ = 2844; $N$ = 318,097).

| Susceptibility constructs | Total | | | Hispanic | | | Non-Hispanic | | |
|---|---|---|---|---|---|---|---|---|---|
| | Factor loading | S.E. | $p$-Value | Factor loading | S.E. | $p$-Value | Factor loading | S.E. | $p$-Value |
| **E-cigarettes** | | | | | | | | | |
| Curiosity | 0.802 | 0.036 | < 0.001 | 0.781 | 0.050 | < 0.001 | 0.824 | 0.041 | < 0.001 |
| Intention | 0.865 | 0.029 | < 0.001 | 0.825 | 0.049 | < 0.001 | 0.914 | 0.026 | < 0.001 |
| Friends | 0.980 | 0.029 | < 0.001 | 1.000 | 0.041 | < 0.001 | 0.958 | 0.031 | < 0.001 |
| **Cigarettes** | | | | | | | | | |
| Curiosity | 0.644 | 0.070 | < 0.001 | 0.565 | 0.111 | < 0.001 | 0.735 | 0.079 | < 0.001 |
| Intention | 0.856 | 0.054 | < 0.001 | 0.888 | 0.090 | < 0.001 | 0.831 | 0.054 | < 0.001 |
| Friends | 0.904 | 0.055 | < 0.001 | 0.858 | 0.072 | < 0.001 | 0.948 | 0.073 | < 0.001 |
| **Hookah** | | | | | | | | | |
| Curiosity | 0.818 | 0.043 | < 0.001 | 0.792 | 0.071 | < 0.001 | 0.854 | 0.053 | < 0.001 |
| Intention | 0.934 | 0.024 | < 0.001 | 0.949 | 0.032 | < 0.001 | 0.912 | 0.031 | < 0.001 |
| Friends | 0.951 | 0.025 | < 0.001 | 0.959 | 0.033 | < 0.001 | 0.935 | 0.034 | < 0.001 |
| **Cigars** | | | | | | | | | |
| Curiosity | 0.755 | 0.052 | < 0.001 | 0.728 | 0.076 | < 0.001 | 0.796 | 0.052 | < 0.001 |
| Intention | 0.928 | 0.042 | < 0.001 | 0.909 | 0.064 | < 0.001 | 0.943 | 0.045 | < 0.001 |
| Friends | 0.897 | 0.049 | < 0.001 | 0.931 | 0.070 | < 0.001 | 0.858 | 0.066 | < 0.001 |

Note: SE = standard error. Cigars include large cigars, cigarillos, and little filtered cigars. Factor loadings for each confirmatory factor analysis model are a measure of how well each specific item loads onto the respective factor (i.e., susceptibility construct), ranging from 0 (poor association) to 1 (strong association).

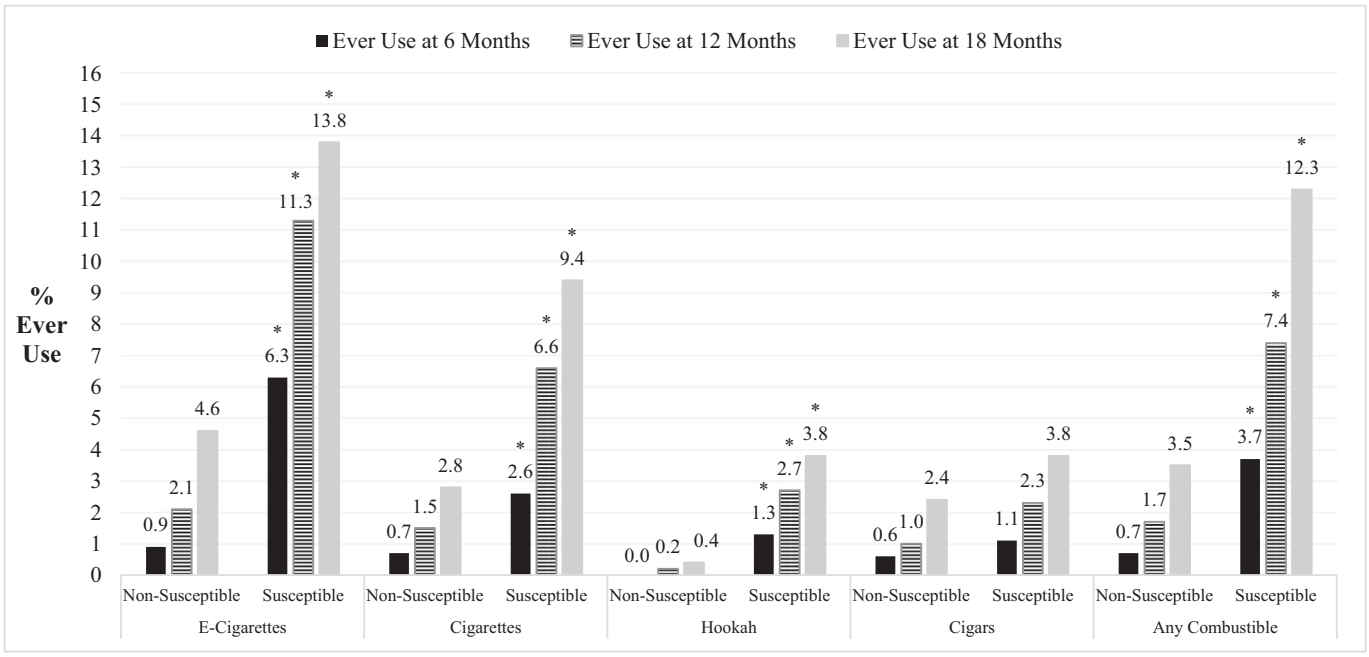


**Fig. 1.** Comparison of susceptibility at baseline among never users and subsequent ever use of each product at 6, 12, and 18 months. *Note*: * indicates $p < 0.05$ for the Chi-square test of group differences in ever use of each specific product at each time point by susceptibility status for each specific product at baseline.

12 months and 5.9% at 18 months, versus 0.9% and 1.7% of non-susceptible adolescents, respectively ($p < 0.05$ for both).

In the adjusted logistic regression models (Table 3) examining the association between susceptibility and ever use at 6, 12, and 18 months for e-cigarettes, age was the only covariate significantly associated with ever use at any time point. Each year increase in age was associated with 1.46 (95% CI: 1.17–1.82), 1.55 (95% CI: 1.31–1.84), and 1.33 (95% CI: 1.08–1.64) times higher odds of e-cigarette ever use at 6, 12, and 18 months, respectively. Similarly, susceptibility to e-cigarettes significantly predicted ever use across time points, with susceptible adolescents having 6.64 (95% CI: 3.39–13.00), 5.01 (95% CI: 2.69–9.34), and 2.88 (95% CI: 1.66–4.97) times higher odds of e-cigarette ever use at 6, 12, and 18 months, respectively, compared to non-susceptible adolescents.

For models considering any combustible product, age was significantly associated with ever use, with each year increase in age being associated with 1.33 (95% CI: 1.09–1.62) and 1.34 (95% CI: 1.16–1.54) times higher odds of ever use of any combustible product at 12 and 18 months, respectively. Similarly, susceptibility to any combustible product significantly predicted ever use at all time points, with susceptible adolescents having 5.20 (95% CI: 1.92–14.07), 3.89 (95% CI: 2.17–6.95), and 3.38 (95% CI: 2.03–5.62) times higher odds of ever use of any combustible product at 6, 12, and 18 months, respectively, compared to non-susceptible adolescents. There were no significant interactions between ethnicity and susceptibility to e-cigarettes or any combustible product at any time point.

## 4. Discussion

Among this population of Texas adolescents, we observed the three-item susceptibility measure adapted from Pierce et al. (2005) was robust across tobacco products and ethnic groups. Consistent with our first hypothesis and past research examining susceptibility in the context of cigarettes (Nodora et al., 2014; Pierce et al., 1996, 2005), we

**Table 3**
Adjusted logistic regression of susceptibility to each product at baseline on ever use at 6 months, 12 months, and 18 months among never users at baseline ($n = 2844$; $N = 318{,}097$ at baseline).

| Variable | | Ever use at 6 months | | | Ever use at 12 months | | | Ever use at 18 months | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | OR | 95% CI | *p*-Value | OR | 95% CI | *p*-Value | OR | 95% CI | *p*-Value |
| **E-cigarettes** | | | | | | | | | | |
| Sex (ref: female) | Male | 1.30 | 0.61–2.76 | 0.488 | 1.08 | 0.73–1.61 | 0.700 | 1.31 | 0.88–1.96 | 0.185 |
| Age | | 1.46 | 1.17–1.82 | 0.001 | 1.55 | 1.31–1.84 | < 0.001 | 1.33 | 1.08–1.64 | 0.008 |
| Family SES (ref: middle) | High | 1.65 | 0.55–4.98 | 0.368 | 1.00 | 0.45–2.20 | 0.993 | 1.24 | 0.63–2.44 | 0.521 |
| | Low | 0.64 | 0.22–1.89 | 0.412 | 0.45 | 0.18–1.12 | 0.085 | 0.83 | 0.33–2.07 | 0.682 |
| Ethnicity (ref: non-Hispanic) | Hispanic | 1.29 | 0.60–2.76 | 0.599 | 0.99 | 0.60–1.63 | 0.966 | 0.93 | 0.60–1.44 | 0.740 |
| Susceptible to e-cigarettes (ref: no) | Yes | 6.64 | 3.39–13.00 | < 0.001 | 5.01 | 2.69–9.34 | < 0.001 | 2.88 | 1.66–4.97 | < 0.001 |
| **Any combustible product** | | | | | | | | | | |
| Sex (ref: female) | Male | 0.85 | 0.33–2.15 | 0.725 | 0.97 | 0.50–1.89 | 0.920 | 1.05 | 0.59–1.87 | 0.867 |
| Age | | 1.18 | 0.88–1.59 | 0.267 | 1.33 | 1.09–1.62 | 0.005 | 1.34 | 1.16–1.54 | < 0.001 |
| Family SES (ref: middle) | High | 0.54 | 0.10–2.81 | 0.458 | 1.17 | 0.58–2.38 | 0.662 | 1.30 | 0.74–2.26 | 0.356 |
| | Low | 1.08 | 0.29–4.03 | 0.904 | 1.21 | 0.49–3.03 | 0.673 | 1.19 | 0.59–2.43 | 0.620 |
| Ethnicity (ref: non-Hispanic) | Hispanic | 0.74 | 0.27–2.14 | 0.575 | 0.97 | 0.48–1.95 | 0.930 | 0.99 | 0.61–1.63 | 0.983 |
| Susceptible to any combustible (ref: no) | Yes | 5.20 | 1.92–14.07 | 0.001 | 3.89 | 2.17–6.95 | < 0.001 | 3.38 | 2.03–5.62 | < 0.001 |

Note: OR = odds ratio, CI = confidence interval, SES = socioeconomic status. “Any combustible” includes cigarettes, cigars, and hookah.

confirmed curiosity, intention to use, and peer influence are significant and appropriate items to consider in measuring susceptibility to e-cigarettes, cigarettes, hookah, and cigars among this adolescent population. Across products, we observed minor differences in the strength of each item. Specifically, curiosity had the weakest relationship with the underlying susceptibility construct across all products, peer influence had the strongest relationship with susceptibility to e-cigarettes, cigarettes, and hookah, and future intentions had the strongest relationship with susceptibility to cigars. While all three factors may be influential in determining adolescent susceptibility to tobacco products, intervention efforts to alter susceptibility may need to be tailored by product.

We observed almost 30% of adolescents were susceptible to e-cigarettes at baseline, a prevalence nearly double that of each individual combustible product. Adolescents may be more susceptible to e-cigarettes than other products, and more research is needed to investigate factors driving increased susceptibility, like the appeal of flavors (Ambrose et al., 2015) or increased television and digital media marketing (Duke et al., 2014; Mantey, Cooper, Clendennen, Pasch, & Perry, 2016; Pierce et al., 2017). As expected, we observed susceptibility to e-cigarettes and combustible products predicts product use at time points 6, 12, and 18 months in the future. This is consistent with previous research (Bold et al., 2017; Cole et al., 2017; Jackson, 1998; Jackson & Dickinson, 2004; Nodora et al., 2014; Pierce et al., 1996, 2005; Spelman et al., 2009; Strong et al., 2015; Unger et al., 1997) and suggests targeting and lessening susceptibility through intervention efforts remains a significant factor in preventing initiation of multiple forms of product use among adolescents.

Of note, the declining magnitude of the odds ratios predicting initiation from any combustible product over time was not statistically different from each other, based on a comparison of their 95% confidence intervals. In contrast, the declining odds ratios for susceptibility to e-cigarette use over time show a significant drop in influence on ever use at 18 months from susceptibility assessed at baseline. This suggests that by 18 months when compared to 6 and 12 months, other factors exert a stronger influence on experimentation relative to susceptibility status assessed 18 months earlier. In turn, this suggests that assessing susceptibility to e-cigarettes more frequently may be necessary to inform the development of targeted long-term interventions, as is identification of other factors that may be proximally related to e-cigarette use.

Congruous with our second hypothesis, we found the measurement of each susceptibility construct across products applied equally well across ethnic groups. Results among groups were consistent with the entire population, with minor differences. Among Hispanic adolescents, intention to use had the strongest relationship with susceptibility to cigarettes, while peer influence had the strongest relationship among non-Hispanic adolescents. In contrast, peer influence had the strongest relationship with susceptibility to cigars among Hispanic adolescents, while intention to use had the strongest relationship among non-Hispanic adolescents. Additionally, ethnicity was significant to the measurement of susceptibility to e-cigarettes as a whole; the differences in the model when considering ethnicity suggest that while the measurement of susceptibility to e-cigarettes is valid across ethnic groups, the meaning of the construct may vary slightly depending on ethnicity. Thus, while it is appropriate to utilize the same susceptibility measure across ethnic groups, specific influences may be more relevant to predicting susceptibility for Hispanics vs. non-Hispanics depending on product type, and specifically, susceptibility to e-cigarettes should be considered separately by ethnicity.

While we expected Hispanic adolescents would have a higher prevalence of susceptibility to each product than non-Hispanic adolescents, this was observed only for e-cigarettes and cigarettes, with curiosity about these products endorsed more often among Hispanic adolescents. This is consistent with previous research (Margolis et al., 2016), and notable, as curiosity predicts future experimentation with smoking independent of susceptibility (Pierce et al., 2005), warranting further examination of factors leading Hispanic adolescents to be more curious about these products. Despite a higher reported prevalence of susceptibility to e-cigarettes and cigarettes among Hispanic adolescents, no significant interactions were observed between ethnicity and susceptibility in predicting future use. Although more Hispanic adolescents are susceptible to e-cigarettes and cigarettes than their non-Hispanic peers (and Hispanic adolescents endorse curiosity about products more than non-Hispanic peers), the relationship between the measure of susceptibility itself and ever use of e-cigarettes and cigarettes is consistent across ethnic groups. This suggests that tailoring interventions designed to ameliorate susceptibility among Hispanics to address curiosity might be particularly useful.

### 4.1. Strengths and limitations

One study limitation is the low prevalence of ever users at future time points for specific products, like hookah and cigars. This prevented examination of susceptibility to these products separately at baseline regarding future use; thus, we cannot draw conclusions about specific predictive validity of susceptibility to individual combustible products. Still, our examination of combustible products as a whole provides evidence for susceptibility as a predictor of product use among adolescents. Additionally, our three-item construct only includes a single measure of intentions to use tobacco in the future, rather than both measures originally considered by Pierce et al. (2005), which may limit the ability to make comparisons between our susceptibility measures and those used in other studies. Next, this study population is limited by geography, so findings may not be generalizable to adolescents outside Texas. Finally, despite utilizing measures adapted from established surveys (Hyland et al., 2017) and thorough cognitive testing, self-report of data may lead to response bias.

Despite limitations, this study is strengthened by the large, diverse population of Texas adolescents, which provided adequate power to examine specific associations across ethnic groups and products. The complex survey design and use of analyses accounting for sampling weights and clustering within schools yield results representative of the overall population of urban Texas adolescents in grades 6, 8, and 10. This study's longitudinal design and breadth of tobacco products allows for investigation of all products concurrently, within the same population and across time points, permitting temporal conclusions about the role of susceptibility on future initiation, and extending past research, which has yet to examine multiple product types longitudinally among the same cohort.

### 4.2. Conclusions

Susceptibility is a key construct for predicting future initiation of tobacco; past research has examined its validity relevant to cigarettes, but not among contemporary adolescent populations and the changing landscape of tobacco products. This study confirms the appropriateness of the measurement of susceptibility (Pierce et al., 2005) across four products (e-cigarettes, hookah, cigars, and cigarettes) and ethnic groups (Hispanic versus non-Hispanic), and the utility of susceptibility in predicting future tobacco product use among adolescents. Implications for intervention and research emphasize the importance of susceptibility in predicting initiation of product use and the need to investigate factors influencing susceptibility to specific products, like e-cigarettes, especially among Hispanic adolescents.

## Compliance with ethical standards

### Ethical approval

TATAMS was approved by the University of Texas Health Science Center at Houston Institutional Review Board (HSC-SPH-13-0377). All

procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors.

*Informed consent*

Informed consent was obtained from all individual participants included in the study.

*Role of funding sources*

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*Contributors*

FRC and EAC conducted the analysis. FRC led the writing and completed the initial draft. AVW and MBH conceptualized and supervised the analysis, and provided critical feedback. CLP provided critical feedback.

*Conflict of interest*

The authors declare that they have no conflict of interest.

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