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Retail Outlets Prompt Associative Memories Linked to the Repeated Use of Nicotine and Tobacco Products among Alternative High School Students in California

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Abstract

Numerous studies have examined how youth are influenced by the presence of tobacco retail outlets that use point-of-sale marketing tactics to promote nicotine and tobacco products. The current investigation extends this research by assessing whether tobacco retail outlets function as environmental cues that prompt associative memories linked to the repeated use of cigarettes, electronic cigarettes, and cigars. Students (N = 1,060) from 29 alternative high schools in California were recruited into a three-year cohort study. A repeated measures latent profile analysis was conducted to identify latent subgroups of students. Analyses suggested the presence of one subgroup of students that did not use nicotine and tobacco products and five subgroups of students that used multiple products. A multinomial logistic regression revealed that images of gas stations, convenience stores, and liquor stores presented in the first year of the study prompted spontaneous associations in memory that increased the odds a student would belong to one of the five subgroups that repeatedly used nicotine and tobacco products over a three-year period. These findings suggest that tobacco retail outlets may act as environmental cues that prompt the use of addictive products among at-risk youth. Policymakers should consider implementing strategies that reduce the potency and prevalence of these cues.

Keywords

Marketing; Habits; Tobacco Use; Nicotine Addiction; Latent Profile Analysis

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Contributors

JP conceived and drafted the manuscript. Analyses were performed by JP with guidance from YS and BX. YS, NT, BX, and AS edited the manuscript for content. JP, BX, and AS conceptualized the larger project and data collection methods. All authors reviewed and approved the final version.

Conflict of Interest

None.

INTRODUCTION[1]

Making Responsible Decisions at the Point-of-Sale

Picture the scenario. A 16-year old student in California finishes her school day and begins walking home. In the distance, she sees a convenience store and spontaneously thinks ‘soda’ and ‘cigarettes.’ As she gets closer, she notices six exterior ads for cigarettes (Henriksen, Feighery, Schleicher, Haladjian, & Fortmann, 2004) and one for electronic cigarettes (Miller, et al., 2017). Out of habit, she enters the store and is immediately exposed to twenty-five ads for cigarettes (Henriksen, Feighery, Schleicher, Haladjian, & Fortmann, 2004) and fifteen for e-cigarettes (Miller, et al., 2017). As she waits in line to pay for her soda, she sees that it costs $5.35 USD for a pack of Marlboro cigarettes, $10.10 USD for a disposable Blu e-cigarette, and $1.03 USD for two Swisher Sweets cigars (Beleva, et al., 2018). She considers buying the e-cigarette but it is too costly so she chooses the cigars (Delnevo, Giovenco, & Miller Lo, 2017). She purchases the product even though she is underage (Landrine, Klonoff, & Alcaraz, 1996). Under current tobacco control policy in the United States, this is the environment in which youth are expected to make a reasoned decision about the consequences of using nicotine and tobacco products (NTPs).

The dangers of NTPs have been thoroughly documented. In the United States, cigars are estimated to cause 9,000 premature deaths each year (Nonnemaker, Rostron, Hall, MacMonegle, & Apelberg, 2014). Cigarettes are estimated to cause 480,000 premature deaths (US Department of Health and Human Services, 2014). The long-term impact of e-cigarettes is unknown but like cigarettes (US Department of Health and Human Services, 2014) and cigars (Chang, Corey, Rostron, & Apelberg, 2015) the product contains carcinogens (Goniewicz, et al., 2014) and poses serious health risks (Pisinger & Dossing, 2014; US Department of Health and Human Services, 2016). Despite this, retail outlets are permitted to sell NTPs within walking distance of schools (Finan, et al., 2018) and use point-of-sale (POS) marketing tactics (Ribisl, et al., 2017) to promote these addictive products. In 2016, over 6 billion USD was spent promoting cigarettes in stores (Federal Trade Commission, 2018). The amount spent on cigars and e-cigarettes is not systematically monitored but current evidence suggests that more than two-thirds of middle school and high school students in the United States have been exposed to POS advertising for e-cigarettes (Marynak, Gentzke, Wang, Neff, & King, 2018).

Numerous studies have shown that tobacco retail outlet (TRO) density is associated with experimentation with cigarettes (Lipperman-Kreda, Grube, & Friend, 2012; McCarthy, et al., 2009) and cigars (Cantrell, et al., 2016). Systematic reviews suggest a causal relationship between exposure to POS tobacco marketing and youth cigarette use (Lovato, Watts, & Stead, 2011; Robertson, McGee, Marsh, & Hoek, 2015). Longitudinal studies have provided evidence for a dose-response relationship between exposure to POS marketing and the use of cigarettes (Hanewinkel, Isensee, Sargent, & Morgenstern, 2011; Henriksen, Schleicher,

[1]Abbreviations: AHS = Alternative High School, AIC = Akaike’s Information Criterion, APP = Average Posterior Probabilities, BIC = Bayesian Information Criterion, NTP = Nicotine and Tobacco Product, POS = Point of Sale, RMLCA = Repeated Measures Latent Class Analysis, RMLPA = Repeated Measures Latent Profile Analysis, SSA-BIC = Sample size adjusted Bayesian Information Criterion, TOMA = Top of Mind Awareness, TRO = Tobacco Retail Outlets

Feighery, & Fortmann, 2010), e-cigarettes, and cigars (Beleva, et al., 2018). Based on these findings, it is not surprising that more and more youth are choosing to smoke a variety of NTPs (El-Toukhy, Sabado, & Choi, 2017). Current estimates suggest that in the United States over 3 million high school students have used e-cigarettes, over 1 million have used cigarettes, and over 1 million have used cigars in the past 30 days (Gentzke, et al., 2019). An estimated 1.68 million high school students have used two or more products in the same timeframe.

How Tobacco Retail Outlets Influence Habitual Behavior

Many of the mechanisms through which TROs facilitate the use of NTPs are easily discernible. TROs offer a means of purchasing NTPs and certain types of TROs, such as gas stations, convenience stores, and liquor stores (Feighery, Ribisl, Shleicher, & Halvorson, 2001; Miller, et al., 2017), have a large number of ads promoting specific brands (National Cancer Institute, 2008). What may be less apparent is the role that TROs play in establishing and perpetuating habits. Habits can be conceptualized as links between cues and behaviors (Hull, 1943; James, 1890; Wood & Rünger, 2016). At a neurological level, habits are characterized by lesser activation in the prefrontal areas of the brain associated with the cognitive control of behavior and greater activation in the basal ganglia (Sjoerds, Luigjes, Van Den Brink, Denys, & Yucel, 2014; Yin & Knowlton, 2006a). Habits can be formed through temporal proximity (i.e. Hebbian learning) and are strengthened by reward mechanisms such as the pharmacological effects of nicotine (Wood, 2017). Over time, habits can become so strong that cues that seem innocuous may trigger unwanted behaviors (Yin & Knowlton, 2006b; Wood & Neal, 2007).

Multiple prospective studies have found that associative memories predict unhealthy habitual behaviors including the use of alcohol (Ames, Xie, Shono, & Stacy, 2017; Kelly, Masterman, & Marlatt, 2005; Salemink & Wiers, 2014; Stacy, 1997) and marijuana (Ames, Xie, Shono, & Stacy, 2017; Shono, Edwards, Ames, & Stacy, 2018; Stacy, 1997). Research suggests that cues prompt spontaneous associations in memory which can activate a behavioral sequence that may circumvent reasoned decision-making (Stacy, Ames, & Knowlton, 2004; Wiers, et al., 2007; Wiers & Stacy, 2006). Although most studies examine a range of cues (Ames, Xie, Shono, & Stacy, 2017; Shono, Edwards, Ames, & Stacy, 2018; Stacy, 1997), from a policy perspective there is value to narrowing the investigation to TROs frequented by youth (Henriksen, Feighery, Schleicher, Haladjian, & Fortmann, 2004; Sanders-Jackson, Parikh, Schleicher, Fortmann, & Henriksen, 2015). If these TROs function as cues that encourage the use of NTPs, then regulations can be enacted to limit the prevalence and potency of the cues (Henriksen, 2012).

The effect of TROs on associative memories and the subsequent use of NTPs can be assessed utilizing various types of top-of-mind awareness (TOMA) measures. Assessments using TOMA date back to the pioneering work of Galton (1880). For decades, TOMA has been used in marketing to assess the salience (Miller & Berry, 1998) of brands and products in the minds of consumers (Axelrod, 1968; Axelrod, 1980; Gruber, 1969; Keller, 1993; Keller, 2012; Taylor & Fiske, 1978). In TOMA research, consumers are presented with a cue and asked to report the first brand or product that comes to mind. If a consumer

spontaneously associates a cue with a specific brand or product, then that cue can be presented again at the right moment to influence behavior. Locations (e.g. movie theaters) that operate as cues to behavior (e.g. eating popcorn) are particularly powerful because they may trigger a habit (Neal, Wood, Wu, & Kurlander, 2011) while simultaneously providing the means to enact the behavior. The same mechanism may allow certain types of TROs to perpetuate habitual NTP use among subgroups of youth. The TOMA assessment utilized in the current investigation was designed to tap into this process by measuring associations in memory between TROs and NTPs.

Using Latent Subgroup Analysis to Examine the Repeated Use of Multiple Products

Latent subgroup analyses are designed to detect clusters of similar individuals within heterogeneous populations. Instead of examining how an independent variable (e.g. gender) influences a dependent variable (e.g. cigarette use), researchers can assess whether an independent variable is associated with membership in a subgroup (e.g. students who use multiple NTPs). For example, latent class analysis (Lazarsfeld, 1950; Lazarsfeld & Henry, 1968) has been applied to dichotomous indicators of tobacco use to distinguish nonusers from polytobacco users and to reveal that males are more likely to be poly-tobacco users (Gilreath, et al., 2016). The same technique has been extended to models with continuous indicators (Gibson, 1959; Lazarsfeld & Henry, 1968) and termed latent profile analysis.

When examining longitudinal data, researchers have identified subgroups by adapting latent growth curve models (Duncan, Duncan, Stryker, Li, & Alpert, 2006) into models that detect distinct developmental trajectories (Muthén, 2001a; Muthén, 2001b; Nagin, 1999). These techniques have been used to understand why one group of individuals may abstain from smoking cigarettes while another develops a lifelong habit during adolescence (Chassin, Presson, Pitts, & Sherman, 2000; Costello, Dierker, Jones, & Rose, 2008; Xie, Palmer, Yan, Lin, & Johnson, 2013). A limitation of these studies is that they are often designed to chart the rise and fall in the use of a single product over time by fitting continuous polynomial functions. In the modern NTP landscape, the diversity of products may cause youth to exhibit discontinuous patterns as they transition from one product to another (Soneji, et al., 2017) or use multiple NTPs (Gilreath, et al., 2016; Haardörfer, et al., 2016). Given that subgroups of individuals who use multiple NTPs report greater levels of nicotine dependence (Sung, Wang, Yao, Lightwood, & Max, 2018; Timberlake, 2008) and may be at greater risk for developing tobacco-related diseases (Backinger, et al., 2008), a closer examination of the factors that may contribute to the discontinuous but repeated use of NTPs is warranted.

In the present study, a repeated measures latent class analysis (RMLCA; Collins & Lanza, 2010) was adapted into a repeated measures latent profile analysis (RMLPA) to investigate the use of multiple NTPs over a three-year period. This form of analysis was chosen to capture the complex and potentially discontinuous longitudinal behavioral patterns that may exist among at-risk youth (Johnson, McMorris, & Kubik, 2013) attending alternative high schools (AHS). To our knowledge, no prior study has examined the repeated use of multiple NTPs in a population known to exhibit high rates of cigarette (Barnett, et al., 2013; Pokhrel, Sussman, & Stacy, 2014), e-cigarette (Miller, Pike, Stacy, Xie, & Ames, 2017), and cigar use

(Beleva, et al., 2018). Furthermore, no study has tested whether TROs frequented by AHS students (Beleva, et al., 2018) act as cues that prompt associative memories that are linked to membership in subgroups of students who use multiple NTPs.

METHODS

Sampling

Data provided by the California Department of Education was used to identify 183 alternative high schools that had at least 100 students and were within 100 miles of the program offices in Claremont, California. On February 6th, 2014 research staff began contacting each school in a randomly selected order. All schools were invited to participate in accordance with the protocol approved by the Claremont Graduate University Institutional Review Board. Schools were accepted on a first-come, first-served basis until 29 sites were enrolled. By June 5th, 2014 each participating school provided a letter confirming their involvement.

Research staff visited the schools between October 14th, 2014 and May 18th, 2015. Interest forms were distributed to 6,870 students who were in attendance at the schools. Completed forms were returned by 2,726 students. The response rate was 39.7% (2726/6870). Each student that returned a form was assigned to a specific staff member. The staff member obtained written consent and provided a link to a web-based survey. Parental consent and youth assent were obtained for students under the age of 18. All students were given until September 1st, 2015 to complete the approximately 90-minute survey. A total of 1,060 students took part in the first assessment for a completion rate of 15.4% (1060/6870). Each of these students was given a $45 gift card to compensate them for their time.

Research staff maintained contact with the students using established procedures (Booker, Harding, & Benzeval, 2011; Hall, et al., 2003; McCuller, Sussman, Holiday, Craig, & Dent, 2002; Scott, 2004). One-year follow-up assessments were completed by 892 students. An additional 31 students without access to a web-enabled device completed a computer-assisted telephone interview. All assessments were administered between September 21st, 2015 and September 1st, 2016. The average length of time between the first assessment and the second assessment was 330 days (SD = 26.6). The retention rate was 87.1% (923/1060). Among the 137 students who did not complete the second assessment, 93.5% failed to respond to repeated contact attempts, 5.8% withdrew from the study, and 0.7% were incarcerated. Each student that completed the second assessment received a $50 gift card.

The retention rate for the two-year follow-up was 81.0% (859/1060). 832 students completed a web-based survey while 27 students completed a computer-assisted telephone interview. All assessments occurred between September 26th, 2016 and September 1st, 2017. The average assessment took place 695 days (SD = 33.7) after the first assessment. Among the 201 students that did not complete the third assessment, 93.0% failed to respond to repeated contact attempts, 4.5% withdrew from the study, 1.5% had died, 0.5% were incarcerated, and 0.5% were deployed overseas after enrolling in the military. A $100 gift card was provided to each student that completed the third assessment.

Measures

Demographics.—Students were asked to report their gender and ethnicity. Students also provided their birthdate which was used to calculate their age at the initial assessment.

Exposure to Advertising for Nicotine and Tobacco Products Outside the Retail Environment (α = .86).—To examine the influence of advertising that occurs outside of TROs, a four-item scale was adapted from the Youth Tobacco Survey (Centers for Disease Control and Prevention, 2014). The scale assessed the extent to which students had been exposed to (a) television commercials, (b) online ads, (c) newspaper and magazine ads, and (d) radio spots for NTPs. Response options included '*None*', '*1-3 times in the past 30 days*', '*1-3 times per week*', '*Daily or almost daily*', and '*More than once a day*'. The mean of these four items was computed for each student.

Frequency of Visits to Gas Stations, Convenience Stores, and Liquor Stores (α = . 65).—A modified version of a previously validated scale (Henriksen, Feighery, Schleicher, Haladjian, & Fortmann, 2004; Feighery, Henriksen, Wang, Schleicher, & Fortmann, 2006) was used to determine the frequency with which students visited gas stations, convenience stores, and liquor stores. Students indicated whether they visited each type of store '*Never*', '*Once a month*', '*Two or three times a month*', '*Once a week*', '*Two or three times a week*', or '*Almost every day*'. The mean of the six-point scale was calculated for each student.

Associative Memories Prompted by Images of Gas Stations, Convenience Stores, and Liquor Stores (α = .77).—In July and August of 2014, Samsung Galaxy S III phones were used to photograph TROs near alternative high schools for a separate investigation of POS marketing (Miller, et al., 2017). Many of the photographs were of stores that were within walking distance of schools that were eligible to enroll in the current study but chose not to participate. From this subset of photographs, one gas station, one convenience store, and one liquor store without exterior POS ads for NTPs were selected. Each image depicted the exterior of the store in the early afternoon without any people present. The store was photographed from the sidewalk to replicate the vantage point of someone walking by. The three images were resized so that no side was greater than 650 pixels. During the survey, each student was informed that they would be presented with an image and asked to quickly enter the first word that came to mind. When these top of mind instructions are used, the response is strongly implicated in implicit memory processes because conscious recollection is not necessary (Levy, Stark, & Squire, 2004; Schacter, 1985; Shimamura & Squire, 1984; Vaidya, Gabrieli, Keane, & Monti, 1995). The task was performed at the beginning of the survey to prevent priming effects (Ames, et al., 2007). After a single practice trial in which students were presented with the image of a fast food store, six images were displayed in a randomly selected order. To prevent response chaining, the photographs of the TROs were interspersed with three photographs of stores that did not sell NTPs. These filler images were generated using the same protocol for photographing TROs. Once the task was completed, students were presented with the word they entered and the image that caused them to think of the word. Utilizing a procedure validated in prior studies (Frigon & Krank, 2009; Krank, Schoenfeld, & Frigon, 2010; Shono, Ames, & Stacy,

2016), the students were asked to indicate whether the word was related to one of fourteen categories (e.g. cigarettes, soda, snacks, etc.). Responses were inspected to ensure that students had selected categories that were plausibly related to the original word. Examples of entries related to NTPs include 'cigarettes', 'swishers', and 'tobacco.' If the student indicated that their response was associated with cigarettes, e-cigarettes, or cigars a value of one was assigned. A sum score was then calculated. A score of zero meant that none of the TROs were spontaneously associated with NTPs while a score of three indicated that all of the TROs were associated with NTPs.

Use of Nicotine and Tobacco Products in the Past Year.—A validated drug use questionnaire (Graham, et al., 1984; Stacy, et al., 1990) was adapted to ask students about their use of (a) cigarettes, (b) e-cigarettes, vaporizers, or vape pens, and (c) cigars, cigarillos, or little cigars in the past year. Response options included '*0 times*', '*1-10 times*', '*11-20 times*', '*21-30 times*', '*31-40 times*', '*41-50 times*', '*51-60 times*', '*61-70 times*', '*71-80 times*', '*81-90 times*', and '*91+ times*'. Although the measure has not yet been validated for novel nicotine products such as vape pens, it has been employed in prior studies to compare the frequency with which at-risk populations use multiple addictive substances including cigarettes (Ames, Xie, Shono, & Stacy, 2017), alcohol (Ames, Grenard, & Stacy, 2013; Ames, Xie, Shono, & Stacy, 2017; Grenard, Ames, & Stacy, 2012), marijuana (Ames, Xie, Shono, & Stacy, 2017; Grenard, Ames, & Stacy, 2012), and methamphetamine (Ames, Grenard, & Stacy, 2013; Grenard, Ames, & Stacy, 2012). The measure was selected so that the use of cigarettes, e-cigarettes, and cigars could be compared on an equal scale. It was administered once per year over a period of three years.

Analyses

The analytic dataset contained 1,060 students nested within 29 schools. Calculating the intra-class correlation revealed that between 2.0% and 5.8% of the variance in the use of cigarettes, e-cigarettes, and cigars could be attributed to random effects at the school level. To account for similarities between students attending the same school, a clustering variable was created that indicated the school each student attended. This variable was integrated into all statistical models. Standard errors robust to non-normality and non-independence of observations were estimated for each model.

An analysis was performed to determine whether students who did not complete the second and third assessments shared common characteristics. Students with missing data at the second assessment were more likely to be male (64.0% vs 47.7%, $p < .001$). No statistically significant differences were detected in the ethnicity of the students (70.4% Hispanic vs 76.3% Hispanic, $p = .498$), their age at the first assessment (17.5 vs 17.4, $p = .176$) or their use of cigarettes (34.3% vs 24.8%, $p = .057$), e-cigarettes (37.6% vs 32.4%, $p = .392$), or cigars (26.3% vs 18.5%, $p = .063$) in the past year at the first assessment. The same pattern persisted at the third assessment. Students with missing data were more likely to be male (62.8% vs 46.8%, $p < .001$). Differences in the ethnicity of the students (72.5% Hispanic vs 76.1% Hispanic, $p = .809$), their initial age (17.5 vs 17.5, $p = .375$), and their initial use of cigarettes (32.6% vs 24.5%, $p = .057$), e-cigarettes (34.7% vs 32.9%, $p = .875$), and cigars (24.1% vs 18.6%, $p = .158$) were not statistically significant. Based on these findings, full-

information maximum likelihood was employed to account for missing data (Graham, 2012; Little & Rubin, 2002). Missing responses in the use of NTPs were assumed to be missing at random conditional on the reported use of these products throughout the three-year study. Covariates that might influence the identification of latent subgroups, such as gender, were excluded from the initial RMLPA model (Nylund-Gibson & Masyn, 2016).

The RMLPA model included nine continuous variables representing the use of cigarettes, e-cigarettes, and cigars in each year of the three-year study. To select the most plausible number of latent subgroups, a series of RMLPA models were tested with between two and seven profiles. Each model used 5,000 random sets of starting values, 20 iterations at the initial stage, and 100 final stage optimizations. The mean and variance of the first subgroup was fixed to zero to delineate students who never used NTPs for the entirety of the three-year study. The best fitting model was selected (Collins & Lanza, 2010; Henson, Reise, & Kim, 2007; Nylund, Asparouhov, & Muthén, 2007; Tofighi & Enders, 2007) by evaluating the log-likelihood, Akaike's Information Criterion (AIC; Akaike, 1987), Bayesian Information Criterion (BIC; Schwarz, 1978), sample size adjusted Bayesian Information Criterion (SSA-BIC; Sclove, 1987), entropy (Celeux & Soromenho, 1996), and average posterior probabilities (APP; Nagin & Odgers, 2010). Using the three-step method (Asparouhov & Muthén, 2014; Vermunt, 2010), a multinomial logistic regression was conducted in which membership in a specific latent subgroup was the dependent variable. The independent variables included in the model were gender (female = 0 vs male =1), ethnicity (non-Hispanic = 0 vs Hispanic =1), age, exposure to NTP advertising outside the retail environment, frequency of visits to TROs, and a TOMA assessment of whether TROs prompted spontaneous associations related to NTPs.

RESULTS

Descriptive Statistics

The sample was 50.7% male and 75.2% Hispanic (see Table 1). The mean age was 17.5 years (SD = 0.9). A sizable portion of the students reported weekly exposure to television commercials (40.4%), online ads (31.8%), newspaper and magazine ads (30.9%), and radio spots (19.8%) for NTPs. Students also reported weekly visits to gas stations (65.3%), convenience stores (48.1%), and liquor stores (43.9%). Nearly one-sixth of the students (16.4%) spontaneously associated an image of one of these stores with an NTP. Compared to students who did not exhibit the same associative memories, these students reported greater use of cigarettes (1.8 vs 0.9, $p < .001$), e-cigarettes (2.1 vs 0.9, $p < .001$), and cigars (1.2 vs 0.6, $p = .002$) in the past year at the first assessment on a scale that ranged from 0 ('*0 times*') to 11 ('*91+ times*'). A similar pattern was observed when comparing the use of cigarettes (1.9 vs 0.9, $p < .001$), e-cigarettes (2.6 vs 1.0, $p < .001$), and cigars (1.0 vs 0.7, $p = .133$) in the past year at the first assessment between students who spontaneously associated two or more TROs with an NTP to those who associated one or fewer TROs with an NTP.

Within the full cohort, the use of only one product (17.3%) was less common than the use of two or more products (24.3%) at the first assessment. At the second assessment, a statistically significant decrease in e-cigarette use was observed (33.3% vs 25.1%, $p = .004$) while changes in the use of cigarettes (26.4% vs 27.7%, $p = .937$) and cigars (19.9% vs

19.0%, $p = .682$) from the first assessment were not statistically significant. An observed decrease in the use of two or more products was also not statistically significant (24.3% vs 21.8%, $p = .313$). A comparison between product use at the first assessment and the third assessment revealed a statistically significant decline in the use of e-cigarettes (33.3% vs 20.6%, $p < .001$) and cigarettes (26.4% vs 21.3%, $p = .042$) but not cigars (19.9% vs 17.5%, $p = .475$). The use of two or more products also declined (24.3% vs 18.3%, $p < .001$).

Identifying Latent Subgroups

The log-likelihood, AIC, BIC, and SSA-BIC steadily decreased with each RMLPA model (see Table 2) leading to the selection of six latent subgroups. A model with seven subgroups was tested but the solution converged to a local maximum (Goodman, 1974). APP and entropy confirmed that the model with six subgroups had good separation with excellent categorization (Nagin & Odgers, 2010).

Nearly half (45.9%) of the students were classified as nonusers (see Figure 1) who did not experiment with cigarettes, e-cigarettes, or cigars at any point during the three-year study. More than a third (37.9%) were designated experimenters who used cigarettes, e-cigarettes, and cigars between zero and ten times each year. The next three subgroups were labeled light users who favored cigarettes (4.8%), e-cigarettes (4.2%), or cigars (4.5%). In a single year, each of these subgroups used all three products between 40 and 160 times. The final subgroup was designated moderate users (2.7%) who collectively used all three products more than 100 times per year.

Independent Variables Associated with Subgroup Membership

A multinomial logistic regression that utilized nonusers as the reference group (see Table 3) revealed that males were more likely to be light e-cigarette users vs nonusers (Odds Ratio [OR] = 3.50, 95% Confidence Intervals [95% CI] = 1.58-7.77, $p = .002$). Hispanics were less likely to be light cigarette users vs nonusers (OR =0.19, 95% CI = 0.08-0.47, $p < .001$) or moderate users vs nonusers (OR = 0.09, 95% CI = 0.03-0.26, $p < .001$). Students who were older at the first assessment were more likely to be light cigarette users vs nonusers (OR = 1.53, 95% CI = 1.12-2.08, $p = .007$) or light e-cigarette users vs nonusers (OR = 1.59, 95% CI = 1.13-2.24, $p = .008$). Exposure to tobacco advertising outside the retail environment was not a statistically significant independent variable in most instances except when comparing light e-cigarette users to nonusers (OR = 1.47, 95% CI = 1.06-2.03, $p = .021$).

The frequency with which students visited TROs was associated with membership in each subgroup. For each increase in the original scale, such as when a student reported visiting TROs ‘Two or three times a month’ instead of ‘Once a month’, the odds were 1.41 times greater that the student would be an experimenter vs a nonuser (95% CI = 1.24-1.61, $p < .001$), 1.92 times greater that the student would be a light cigarette user vs a nonuser (95% CI = 1.38-2.68, $p < .001$), 2.12 times greater that the student would be a light e-cigarette user vs a nonuser (95% CI = 1.56-2.88, $p < .001$), 2.46 times greater that the student would be a light cigar user vs a nonuser (95% CI = 1.92-3.16, $p < .001$), and 3.96 times greater that the student would be a moderate user vs a nonuser (95% CI = 2.07-7.56, $p < .001$).

A similar pattern was observed for students who reported spontaneous associations with TROs that were related to NTPs. For each associative memory linked to an NTP, the odds were 1.25 times greater that the student would be an experimenter vs a nonuser (95% CI = 1.06-1.47, $p = .007$), 1.44 times greater that the student would be a light cigar user vs a nonuser (95% CI = 1.03-2.03, $p = .034$), 1.62 times greater that the student would be a light cigarette user vs a nonuser (95% CI = 1.20-2.20, $p = .002$), 1.92 times greater that the student would be a light e-cigarette user vs a nonuser (95% CI = 1.31-2.81, $p = .001$), and 2.73 times greater that the student would be a moderate user vs a nonuser (95% CI = 1.89-3.94, $p < .001$).

DISCUSSION

Tobacco Retail Outlets and the Repeated Use of Nicotine and Tobacco Products

The current study used RMLPA to identify latent subgroups of AHS students that used cigarettes, e-cigarettes, and cigars over a three-year period. While prior research has employed latent class analysis to denote the existence of subgroups that use multiple NTPs at one point in time (Gilreath, et al., 2016; Haardörfer, et al., 2016), this investigation extends these findings by revealing that the use of NTPs in these subgroups may reoccur year after year. A particularly novel finding is that TROs may function as environmental cues that prompt spontaneous associations linked to the repeated use of NTPs. Beyond serving as locations for obtaining NTPs, the sight of TROs may bring to mind implicit memories which initiate a behavioral sequence that culminates in the use of one or more products. This mechanism may partially explain the findings from a recent meta-analysis (Finan, et al., 2018) indicating that TRO density influences youth cigarette use. Given the broad range of products currently being promoted in TROs (Ribisl, et al., 2017), future studies may find that TRO density is also associated with the use of e-cigarettes (Pérez, et al., 2017) and cigars (Cantrell, et al., 2016).

The repeated use of NTPs has major health implications. Although some researchers argue that the consistent use of e-cigarettes may save lives (Levy, et al., 2018), the potential benefits are moot if more harmful products are still used with enough regularity to reveal clinical sequelae in the future. Moreover, if the use of NTPs are essentially equated in habit formation then occurrences of use of one product could propel the use of all products leading to greater levels of nicotine addiction (Timberlake, 2008; Sung, Wang, Yao, Lightwood, & Max, 2018) and a greater likelihood of relapse during cessation attempts (Messer, et al., 2015).

Limitations

Although the findings presented are compelling several limitations must be noted. RMLPA was used to identify latent subgroups within a sample of AHS students who are themselves an at-risk subgroup within the general youth population in the United States (Johnson & Taliaferro, 2012). In addition, a comparison between the sample and school-level demographics reported by the California Department of Education in 2014 revealed statistically significant differences in the gender (50.7% male vs 59.7% male, $p < .001$) and ethnicity (75.2% Hispanic vs 71.0% Hispanic, $p = .005$) of the longitudinal cohort. These

differences hinder the generalizability of the findings. Future studies should consider applying RMLPA to other longitudinal datasets to confirm whether the same subgroups exist elsewhere and whether those subgroups exhibit comparable patterns of behavior. It may also be informative to use alternative statistical techniques to examine the use of NTPs such as dual-trajectory and triple-trajectory latent growth mixture models (Cho, et al., 2018).

Another limitation is that the current investigation focused on whether or not TROs prompted spontaneous associations related to NTPs but did not delineate the precise source of those associations. Randomized experiments indicate advertising for e-cigarettes influences associative memories (Pokhrel, et al., 2016; Pokhrel, Herzog, Fagan, Unger, & Stacy, 2018). However, the repeated purchase of NTPs at TROs, whether legally or illegally, may also independently or synergistically shape associative memories. Understanding these neurocognitive mechanisms and determining the extent to which they influence both explicit and implicit cognition could be critical to the development of policies that reduce youth use of NTPs.

The current investigation was also limited to self-report measures. Among smokers, self-report measures have been known to produce imprecise estimates of cigarette use (Shiffman, 2009; Stanton, McClelland, Elwood, Ferry, & Silva, 1996; Wang, Shiffman, Griffith, & Heitjan, 2012). Recall bias may have similarly resulted in inaccurate reports of the use of cigarettes, e-cigarettes, and cigars in the past year which could have influenced the identification of the latent subgroups. The measures utilized were also restricted to three NTPs. Future studies may benefit by broadening the range of products used as indicators of the latent subgroups. Given the recent legalization of marijuana in California, the body of evidence documenting the co-occurring use of cannabis and tobacco (Agrawal, Budney, & Lynskey, 2012), and the disproportionately high rates of marijuana use among AHS students (Johnson, McMorris, & Kubik, 2013) it may also be insightful to distinguish between subgroups of youth who separately or simultaneously use multiple substances.

Reducing the Potency and Prevalence of Tobacco Retail Outlets

By understanding the effect of TROs on the use of NTPs, policymakers can begin to develop strategies that disrupt the link between environmental cues and unwanted behaviors.One possible mechanism for achieving this is to enact comprehensive marketing restrictions (Henriksen, 2012). Restrictions would have the practical effect of reducing cues in retail environments frequented by youth (Henriksen, Feighery, Schleicher, Haladjian, & Fortmann, 2004; Sanders-Jackson, Parikh, Schleicher, Fortmann, & Henriksen, 2015) which may cause fewer students to spontaneously associate TROs with NTPs. This form of habit disruption (Wood & Neal, 2016) may partially explain decreases in smoking observed after the implementation of marketing restrictions required by the 1998 Master Settlement Agreement (Iwasaki, Tremblay, & Tremblay, 2006).

An alternative strategy is to decrease the prevalence of TROs (Ashe, Jernigan, Kline, & Galaz, 2003; Cohen & Anglin, 2009; Finan, et al., 2018; Institute of Medicine, 2007). This could be achieved by placing fees on tobacco licenses issued to retailers (Henriksen, 2012), passing moratoriums on the provision of new licenses once a certain threshold is reached (US Department of Health and Human Services, 2000), or by enacting localized restrictions

under the authority granted by the Family Smoking Prevention and Tobacco Control Act (Lange, Hoefges, & Ribisl, 2015). Collectively, these policies might create an environment in which a student is able to walk home from school without being prompted to enter a store promoting addictive, carcinogenic products.

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- Prior research shows that tobacco retail outlets (TROs) influence youth tobacco use
- TROs prompt associations in memory linked to the repeated use of tobacco products
- Policies to reduce tobacco use should consider the effect of TROs on at-risk youth

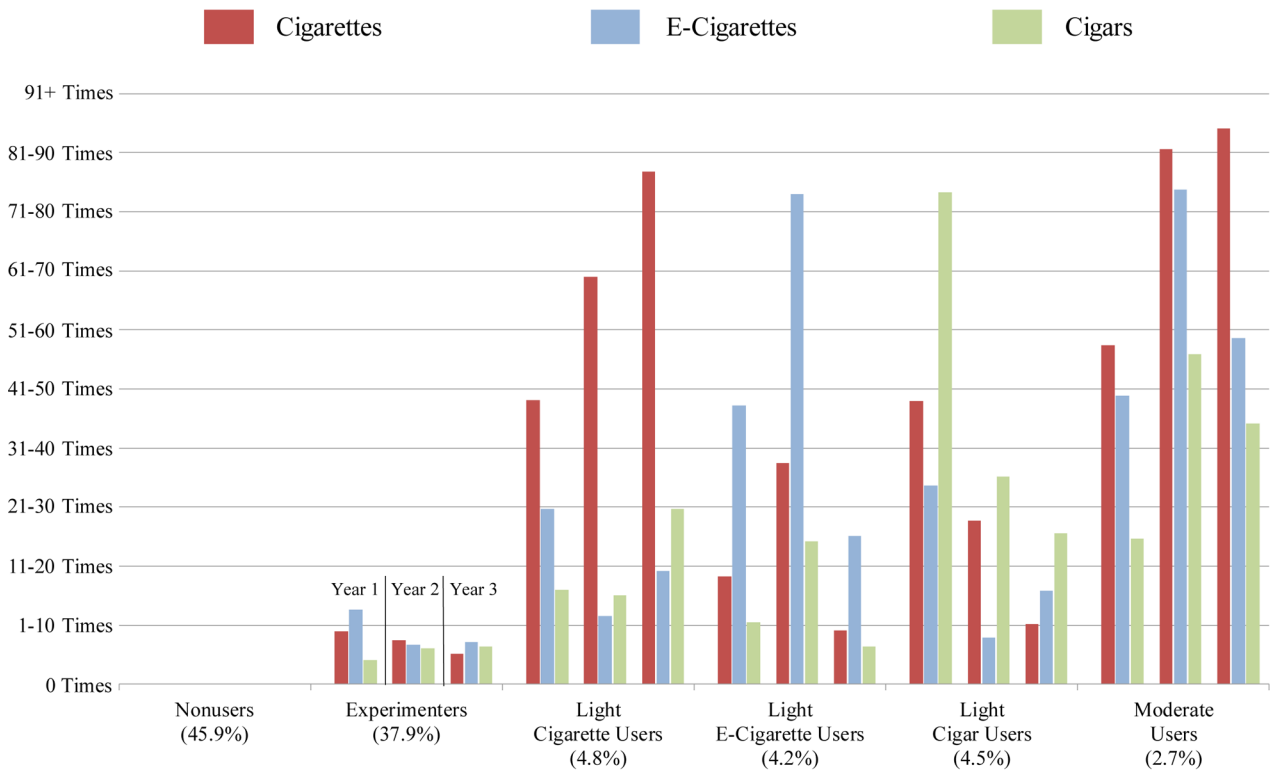

Figure 1. Visual depiction of latent subgroups of alternative high school students (n = 1060) that repeatedly used multiple nicotine and tobacco products over a three-year period

Note: Each bar represents the estimated mean use of a single product in a single year within a latent subgroup. Three bars are present in each year to depict the frequency with which multiple nicotine and tobacco products are used.

Table 1.

Descriptive statistics for longitudinal cohort of alternative high school students (n = 1060) assessed over a three-year period

	Cases n (%)	Complete Cases n (%)
First Assessment		
Gender		
Male	534 (50.7%)	1054 (99.4%)
Female	520 (49.3%)	
Ethnicity		
Hispanic	777 (75.2%)	1033 (97.5%)
Non-Hispanic	256 (24.8%)	
Age		
Less than 17 Years Old	316 (29.9%)	1057 (99.7%)
17 Years Old	440 (41.6%)	
Greater than 17 Years Old	301 (28.5%)	
Weekly Exposure to Advertising for NTPs		
Television Commercials	395 (40.4%)	978 (92.3%)
Online Ads	311 (31.8%)	979 (92.4%)
Newspaper and Magazine Ads	302 (30.9%)	978 (92.3%)
Radio Spots	189 (19.4%)	975 (92.0%)
Weekly TRO Visits		
Gas Stations	676 (65.3%)	1035 (97.6%)
Convenience Stores	493 (48.1%)	1026 (96.8%)
Liquor Stores	453 (43.9%)	1033 (97.5%)
Associative Memories Related to NTPs		
One Spontaneous Association	72 (7.2%)	996 (94.0%)
Two Spontaneous Associations	51 (5.1%)	
Three Spontaneous Associations	41 (4.1%)	
NTPs Used in the Past Year		
Cigarettes	267 (26.4%)	1011 (95.4%)
E-Cigarettes	337 (33.3%)	1012 (95.5%)
Cigars	198 (19.9%)	997 (94.1%)
Only One Product	171 (17.3%)	990 (93.4%)
Two or More Products	241 (24.3%)	990 (93.4%)
Second Assessment		
NTPs Used in the Past Year		
Cigarettes	221 (25.1%)	882 (83.2%)
E-Cigarettes	243 (27.7%)	878 (82.8%)
Cigars	167 (19.0%)	879 (82.9%)
Only One Product	145 (16.7%)	870 (82.1%)
Two or More Products	189 (21.8%)	870 (82.1%)
Third Assessment		

	Cases n (%)	Complete Cases n (%)
NTPs Used in the Past Year		
Cigarettes	175 (21.3%)	820 (77.4%)
E-Cigarettes	169 (20.6%)	820 (77.4%)
Cigars	143 (17.5%)	818 (77.2%)
Only One Product	96 (11.9%)	806 (76.0%)
Two or More Products	148 (18.3%)	807 (76.1%)

Note: Students were permitted to skip survey questions they did not want to answer. Consequently, the number of complete cases from the original cohort of 1,060 students varied for each measure. NTPs = Nicotine and tobacco products. TROs = Gas stations, convenience stores, and liquor stores that sell nicotine and tobacco products.

Table 2.

Summary of information used to identify latent subgroups of alternative high school students (n = 1060) that repeatedly used multiple nicotine and tobacco products over a three-year period

	Two Subgroups	Three Subgroups	Four Subgroups	Five Subgroups	Six Subgroups
Parameters	19	29	39	49	59
Log-likelihood	−2297.547	−1662.729	−1485.865	−1291.637	−1157.255
AIC	4633.094	3383.457	3049.731	2681.274	2432.510
BIC	4727.232	3527.142	3242.961	2924.051	2724.834
SSA-BIC	4666.885	3435.033	3119.092	2768.420	2537.441
Entropy	1.000	0.980	0.979	0.975	0.971
APP	1.000	0.967	0.936	0.918	0.872

Note: AIC = Akaike's Information Criterion, BIC = Bayesian Information Criterion, SSA-BIC = Sample size adjusted Bayesian Information Criterion, and APP = Average Posterior Probabilities.

Table 3.

Odds ratios for multinomial logistic regression depicting the association between measures administered in the first year of the study and membership in subgroups of alternative high school students (n = 1060) that repeatedly used multiple nicotine and tobacco products over a three-year period

	Experimenter vs. Nonuser		Light Cigarette User vs. Nonuser		Light E-Cigarette User vs. Nonuser		Light Cigar User vs. Nonuser		Moderate User vs. Nonuser	
	OR	**[95% CI]**	**OR**	**[95% CI]**	**OR**	**[95% CI]**	**OR**	**[95% CI]**	**OR**	**[95% CI]**
Gender (Male)	0.95	[0.68, 1.32]	0.97	[0.53, 1.79]	3.50	[1.58, 7.77]	1.93	[0.77, 4.86]	2.16	[0.91, 5.14]
Ethnicity (Hispanic)	0.91	[0.61, 1.34]	0.19	[0.08, 0.47]	0.33	[0.11, 1.01]	0.54	[0.21, 1.38]	0.09	[0.03, 0.26]
Age	1.02	[0.88, 1.18]	1.53	[1.12, 2.08]	1.59	[1.13, 2.24]	1.05	[0.60, 1.84]	1.11	[0.60, 2.06]
Advertising Exposure	1.14	[0.96, 1.36]	1.03	[0.77, 1.37]	1.47	[1.06, 2.03]	1.24	[0.89, 1.74]	1.22	[0.73, 2.05]
TRO Visits	1.41	[1.24, 1.61]	1.92	[1.38, 2.68]	2.12	[1.56, 2.88]	2.46	[1.92, 3.16]	3.96	[2.07, 7.56]
Associative Memories	1.25	[1.06, 1.47]	1.62	[1.20, 2.20]	1.92	[1.31, 2.81]	1.44	[1.03, 2.03]	2.73	[1.89, 3.94]

Note: Advertising Exposure = Exposure to newspaper and magazine ads, television commercials, radio spots, and online ads for nicotine and tobacco products, TRO Visits = Frequency of visits to gas stations, convenience stores, and liquor stores, and Associative Memories = Spontaneous associations with gas stations, convenience stores, and liquor stores that are related to the use of nicotine and tobacco products.