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Progression from E-cigarette Use to Conventional Cigarette Smoking among Adolescents in the United States

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Dedication

”Quality education is top priority”

For my mom, Olajumoke Owotomo (1956 - 2014)

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Abstract

Progression from E-cigarette Use to Conventional Cigarette Smoking among Adolescents in the United States

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Conventional cigarette smoking remains a major cause of significant morbidity and mortality in the United States. Although adolescent cigarette smoking rates have declined over the past decades, e-cigarette use is an emerging public health threat that can potentially stall or reverse this decline. Currently, e-cigarette use has become a social norm with its prevalence surpassing that of conventional cigarette smoking among adolescents. Adolescent e-cigarette users are at heightened risk of nicotine addiction and progressing to conventional cigarette smoking. However, factors underlying this progression are yet to be fully elucidated. Using the Theory of Planned Behavior as a conceptual framework, I conducted three studies that aimed to identify factors that potentially underlie progression from e-cigarette use to conventional cigarette smoking among US adolescents. With data obtained from two national surveys on adolescent risk behaviors: Monitoring the Future Survey and Population Assessment on Tobacco and Health, I examined smoking-related perceptions that make adolescent e-cigarette users

susceptible to conventional cigarette smoking (Study 1); identified subgroups of adolescent e-cigarette users at most risk of exhibiting smoking intention (Study 2); and investigated how e-cigarette use moderates the transition from smoking intention to conventional cigarette smoking (Study 3). These three studies identify actionable predictors of conventional cigarette smoking among adolescent e-cigarette users and highlight potential foci for smoking prevention efforts. Findings suggest that negative attitudes and norms toward conventional cigarette smoking are major factors underlying progression to smoking among adolescent e-cigarette users. Also, three distinct subgroups of adolescent e-cigarette users were identified with each having particular smoking-related characteristics that determine their intention to smoke conventional cigarettes. Finally, transition from smoking intention to smoking initiation is moderated by e-cigarette use status, with smoking intention predicting smoking initiation only among adolescent never e-cigarette users. Adolescent e-cigarette users are at risk of progressing to smoking initiation whether or not they exhibit smoking intention, an indication that the influence of e-cigarette use on cigarette smoking may potentially override the protective effect of lack of smoking intention. Adolescents least likely to initiate conventional cigarette smoking in the current tobacco landscape do not have smoking intention and are abstaining from e-cigarettes.

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Chapter 1: Introduction and Background

Tobacco use remains a leading cause of morbidity and mortality in the United States (U.S. Department of Health and Human Services [USDHHS], 2014). Over the past few decades, comprehensive tobacco control interventions have led to significant declines in the prevalence of adolescent conventional cigarette smoking (USDHHS, 2014). During 2011-2018, smoking prevalence declined from 15.8% to 8.1% among high school students and from 4.3% to 1.8% among middle school students (Gentzke et al., 2019). However, disparities in adolescent cigarette smoking remain. For example, in 2017, smoking rates among high school students in West Virginia was 14.4% compared with 3.8% in Utah (Centers for Disease Control and Prevention [CDC], 2018a) and 10.3% among American-Indian/Alaskan Native adolescents (compared with 2% among Asian adolescents) (Odani, Armour, and Agaku, 2018). Adolescents who initiate smoking are at risk of becoming addicted to nicotine which leads to smoking at higher frequency and more difficulty with quitting smoking as adults (USDHHS, 2012). In addition to the risk of nicotine addiction, adolescents who become established smokers as adults are at high risk of developing several disease conditions including heart disease, various forms of cancer, and stroke—the leading causes of deaths among adults in the United States (CDC, 2018b). Because the majority (over 90%) of adults smokers initiate smoking during adolescence (USDHHS, 2014), achieving sustained declines and closing existing disparities in adolescent smoking are necessary to prevent tobacco-related diseases and deaths. Although adolescent cigarette smoking rates have declined significantly, the

emergence of new tobacco products such as e-cigarettes can potentially reverse or stall these trends, thus constituting newer threats to public health (USDHHS, 2016).

E-cigarette use is a risk factor for conventional cigarette smoking among US adolescents (Barrington-Trimis et al., 2016a; Berry et al., 2019; Bold et al., 2018; Leventhal et al., 2015; Miech et al., 2017a; Soneji et al., 2017a; Unger et al., 2016; Wills et al., 2017). It is prospectively associated with both smoking intention and smoking initiation and can potentially lead to nicotine addiction (Barrington-Trimis et al., 2016b; Bunnell et al., 2014; Goldenson et al., 2017; Miech et al., 2017a; Primack et al., 2015; Soneji et al., 2017a). In fact, among adolescents who currently use tobacco products, about 15% use both e-cigarettes and conventional cigarettes (Gentzke et al., 2019). Until recently, e-cigarettes were largely unregulated, contributing to an increase in popularity among adolescents (United States Food and Drug Administration [FDA], 2016; USDHHS, 2016). In December 2018, US Surgeon-General declared youth e-cigarette use as an epidemic owing to the considerable increase in current e-cigarette use (past 30-day use) among adolescents and the increasing popularity of potentially addictive e-cigarette types (e.g. JUUL e-cigarettes) with youth-appealing characteristics (USDHHS, 2018a). During 2017-2018, reported prevalence of e-cigarette use increased from 3.3% to 4.9% among middle school students (48.5% increase) and 11.7% to 20.8% among high school students (77.8% increase) (Gentzke et al., 2019). JUUL e-cigarettes are of particular concern because of their concealable characteristics (small sizes, markedly reduced aerosol, and reduced odor) and addictive potential. A single 5% cartridge or pod of JUUL

e-cigarette (USB flash drive shaped e-cigarette) can deliver as much nicotine as a pack of 20 regular cigarettes (Jackler and Ramamurthi, 2019; USDHHS, 2018a).

Although FDA has begun the process of regulating e-cigarettes, gaps exist in the current regulatory framework. For example, flavors, which is one of the main reasons adolescents find e-cigarettes attractive (Miech, Patrick, O'Malley, and Johnston, 2017b), are yet to be completely banned. Also, there are currently no restrictions on e-cigarettes advertisements on mass media, which may continue to predispose adolescents to e-cigarette use and its associated consequences (CDC 2016; Kornfield et al., 2015; Lou et al., 2014; Mantey et al., 2016; Pasch et al., 2017; Pierce et al., 2017; Pierce et al., 2018; Pokhrel et al., 2015; Tobacco Control Legal Consortium, 2017). However, the FDA recently launched mass-media campaigns to discourage adolescent e-cigarette use (FDA, 2018). Additional interventions that will halt the progression from e-cigarette use to conventional cigarette smoking among current adolescent e-cigarette users are warranted due to the limited knowledge of the long-term effects of the chemical constituents and the potential psychosocial consequences of e-cigarette use including initiation of conventional cigarette smoking and nicotine addiction (Goldenson et al., 2017; National Academies of Sciences, Engineering, and Medicine [NASEM], 2018; USDHSS, 2016). Such interventions will rely on the evidence provided by focused studies that clearly elucidate the underlying characteristics of the adolescent e-cigarette user population that increase their risk of progressing to conventional cigarette smoking.

This introductory chapter will review the trends, etiological factors, and potential consequences of e-cigarette use among US adolescents. It will discuss the guiding

theoretical framework for this dissertation; provide an overview of the current state of the literature on progression from e-cigarette use to conventional cigarette smoking; and summarize the existing gaps in literature. The research purpose, objectives, and conceptual framework for the proposed studies will also be discussed. The chapter ends with research questions and hypotheses for the proposed three studies of this dissertation.

Prevalence and disparities in adolescent e-cigarette use

Trends/Prevalence

The prevalence of adolescent e-cigarette use has risen astronomically since it was first measured by the National Youth Tobacco Survey (NYTS) in 2011 (USDHHS, 2016). The reported past 30-day prevalence of e-cigarette use among adolescents in grades 6-12 rose from 1.1% in 2011 to 11.3 % in 2015. Specifically, in 2015, past 30-day prevalence of e-cigarette use was 5.3% and 16% among middle and high school students, respectively (USDHHS, 2016). Between 2015 to 2016, past 30-day prevalence of adolescent e-cigarette use declined from 10% to 6% among 8th grade students, from 16% to 10% and 16% to 12% among 10th and 12th grade students, respectively (Johnston et al., 2017a). However, most recent estimates from the CDC showed a marked increase in adolescent e-cigarette use during 2011-2018. The prevalence of current e-cigarette use increased significantly from 0.6% to 4.9% among middle school students and from 1.5% to 20.8% among high school students (Gentzke et al., 2019). Of particular note is the remarkable increase in prevalence that occurred during 2017-2018. There was a 48.5% increase in current e-cigarette use (3.3% to 4.9%) among middle school students and 77.8% increase (11.7% to 20.8%) among high school students (Gentzke et al., 2019).

Although it is unclear whether the significant increase in current e-cigarette use that occurred during 2017-2018 was due to improved measures for estimating adolescent e-cigarette use, what remains certain is that a significant proportion of adolescents use e-cigarettes regularly and are at increased risk of becoming conventional cigarette smokers (Johnston et al., 2017a). Currently, prevalence of adolescent e-cigarette use remains higher than that of conventional cigarettes, making e-cigarettes the major substance used by adolescents in the United States (Johnston et al., 2017a).

Racial/ethnic disparities

There are racial/ethnic disparities in adolescent e-cigarette use, with White and Hispanic adolescents being more likely to use e-cigarettes than other racial/ethnic groups (Lanza et al., 2017; USDHHS, 2016). According to 2015 data from NYTS, prevalence of current e-cigarette use among middle school students was highest in Hispanics compared to White and Black students (8.3% vs 4.4% and 4.1% respectively). However, among high school students, both Hispanic and White students had similarly higher rates compared to Black students (17.2%, 16.4%, and 8.9%, respectively) (USDHHS, 2016). This is consistent with findings from another national study that used Time-Varying Effects Modeling (TVEM) to examine trends in e-cigarette use among adolescents (Lanza et al., 2017). Hispanics were found to have the highest prevalence of e-cigarette use, particularly during early adolescence (12-14 years). After age 14 years, prevalence of e-cigarette use was highest among both Hispanic and White, relative to Black adolescents (Lanza et al., 2017). However, based on most recent CDC estimates from 2018, White non-Hispanic high school students currently have the highest prevalence of

current e-cigarette use (26.8% compared with 14.8% and 7.5% among Hispanics and Black non-Hispanics, respectively), and White non-Hispanics and Hispanics share highest rates among middle school students (6.6% and 4.9%, respectively, compared with 3% among Black non-Hispanics) (Gentzke et al., 2019). The burden of adolescent e-cigarette use is highest among White non-Hispanic and Hispanic middle and high school students.

Gender disparities

Between 2011-2015, NYTS found no significant gender differences in past 30-day prevalence of e-cigarette use among middle school students (USDHHS, 2016). However, significant gender differences were found among high school students, with males being more likely to be current e-cigarette users than females, during the same time interval, except in 2014 when no significant differences were noticed. In 2015, past 30-day prevalence was 19% among male compared with 12.8% among female high school students (USDHHS, 2016). These findings are also consistent with those of Lanza et al, who found no significant gender differences in rates of e-cigarette use among adolescents younger than 14 years, however, between ages 14-17.5 years, males were found to be more likely to be current e-cigarette users than females (Lanza et al., 2017). Currently, based on most recent CDC estimates, male and female middle and high school students do not significantly differ in the prevalence of current e-cigarette use (22.6% vs 18.8% for male and female high school students, respectively; and 4.8 vs 4.2% for male and female middle school students respectively) (Gentzke et al., 2019). Thus, there are currently no gender disparities in adolescent e-cigarette use.

Socioeconomic disparities

National and local studies that examined socioeconomic differences in adolescent e-cigarette use have yielded mixed results. Cross-sectional studies conducted among high school students in Connecticut found that current e-cigarette users were more likely to be low SES than high SES (Simon et al., 2017). However, another study conducted among adolescents in California found the opposite with high SES adolescents being more likely to be e-cigarette users (Alcala et al., 2016). More national studies are needed to assess the role of SES in the adolescent e-cigarette use.

Etiology of adolescent e-cigarette use

The median age of e-cigarette use initiation is 14.1 years, with 30% of adolescent ever e-cigarette users reporting initiating use at ≤13 years (Sharapova et al., 2018). The major factors promoting adolescent e-cigarette use can be classified into smoking-related perceptions (Ambrose et al., 2014; Amrock et al., 2015; Barrington-Trimis et al., 2015; Barrington-Trimis et al., 2016a; Parker et al., 2018; Strong et al., 2019), curiosity about e-cigarettes (Kong et al., 2015; Patrick et al., 2015), unique features of e-cigarettes (Ambrose et al., 2015; Kong et al., 2015; Meich et al., 2017b; Peters et al., 2013), social acceptability of e-cigarettes (Barrington-Trimis et al., 2015; Cardenas et al., 2015), and e-cigarette marketing (CDC 2016; Kornfield et al., 2015; Lou et al., 2014; Mantey et al., 2016; Pierce et al., 2017; Pasch et al., 2017; Pokhrel et al., 2016).

Smoking-related perceptions

A primary reason why adolescents use e-cigarettes is their perception that it is relatively safer than conventional cigarettes. Several studies have established that

adolescents e-cigarette users have lowered perceptions of the harm of e-cigarettes relative to conventional cigarettes (Ambrose et al. 2014; Amrock et al., 2015; Barrington-Trimis et al., 2015, Roditis and Halpern-Felshern, 2015; Roditis et al., 2016; Wills et al., 2015a). For example, in a recent national study, adolescents ever e-cigarette users reported lower perceptions of harm and addictiveness of e-cigarettes than never-users of tobacco products (Strong et al., 2019). A prospective association between low perceptions of e-cigarette use and subsequent initiation of e-cigarette use has also been reported (Parker et al., 2018).

Curiosity about e-cigarettes

E-cigarettes are relatively new tobacco products that are currently marketed as safe alternatives to conventional cigarettes. Inquisitiveness about e-cigarettes is another factor driving e-cigarette use among adolescents (Kong et al., 2015; Patrick et al., 2016). Curiosity about e-cigarette use was reported to be the main reason for e-cigarette experimentation among adolescents who participated in a focus group study in Connecticut (Kong et al., 2015). In a national study of 8th, 10th, and 12th grade ever-vaporizer users, 53% of participants cited experimentation as the main reason for vaporizer use (Patrick et al., 2016). Other reasons given include boredom, relaxation, and having a good time (Patrick et al., 2016).

Unique features of e-cigarettes

Preference for the unique characteristics of e-cigarettes such as flavorings, taste, and ability to conceal use also promote e-cigarette use among adolescents (Ambrose et al., 2015; Kong et al., 2015; Miech et al., 2017b; Peters et al., 2013). In a national study,

65% of adolescents who had ever used a vaporizer (such as e-cigarettes) reported vaping only flavorings (Meich et al., 2017b). Availability of flavors was cited as the second most common reason for e-cigarette experimentation (after curiosity) in a focus group study conducted among high school students in Connecticut (Kong et al., 2015). Another reason why e-cigarettes appeal to adolescents is the ability to conceal use from others. In a focus group conducted by Peters et al (2013) among 47 male adolescents in Texas, concealment was given as the main reason why young people use e-cigarettes.

Social acceptability of e-cigarettes

Peer and parental use and acceptability of e-cigarette use are also associated with adolescent e-cigarette use. Adolescents who have friends or parents who use e-cigarettes are more likely to also be current e-cigarette users (Barrington-Trimis et al., 2015). In a study conducted among adolescents in Southern California, almost 50% of current adolescent e-cigarette users (compared with 3.4% of never e-cigarette users) had three-to-four friends who also used e-cigarettes, and 34% (compared with 7% of never e-cigarette users) had at least someone at home who also used e-cigarettes. Also, over 90% of e-cigarette users reported that they received positive affirmation from their friends if they used e-cigarettes (Barrrington-Trimis et al., 2015).

E-cigarette marketing

Adolescents who are exposed to or receptive to e-cigarette marketing on media (TV and print) and point-of-sale are more likely to be susceptible to e-cigarette use than those who are not. Receptivity to e-cigarette marketing increases the likelihood of being susceptible to e-cigarette use (CDC 2016; Kornfield et al., 2015; Lou et al., 2014; Mantey

et al., 2016; Pierce et al., 2017; Pierce et al., 2018; Pasch et al., 2017; Pokhrel et al., 2016; Tobacco Control Legal Consortium, 2017). In a longitudinal study on adolescents who participated in the Texas Adolescent Tobacco Advertising and Marketing Surveillance System (TATAMS) study, recollection of e-cigarette marketing signs at baseline was prospectively associated with ever-e-cigarette use and increased susceptibility to e-cigarette use at six-month follow-up. (Pasch et al., 2017).

Consequences of adolescent e-cigarette use

Studies on the consequences of e-cigarette use among adolescents have yielded three major findings: (i) e-cigarette use is prospectively associated with smoking intention or smoking susceptibility (Bunnell et al., 2014; Primack et al., 2015; Wills et al., 2015b) (ii) e-cigarette use is directly associated with initiation of conventional cigarette smoking (Barrington-Trimis et al., 2016a; Leventhal et al., 2015; Miech et al., 2017a; Soneji et al., 2017a; Unger et al., 2016; Wills et al., 2017); and (iii) e-cigarette use may lead to nicotine addiction (Vansickel et al. 2012; Vansickel et al. 2013), which potentially fuels continued e-cigarette use and/or progression to conventional cigarette smoking (Goldenson et al., 2017). Details of these three major psychosocial consequences of e-cigarette use are discussed under literature review.

Few studies have also demonstrated associations between e-cigarette use and subsequent use of other tobacco products such as cigars and hookah (Barnett et al., 2015; Leventhal et al., 2015), and use of substances e.g. marijuana, illicit drugs, and nonmedical prescription drugs (McCabe et al., 2017; Unger et al., 2016). For example, in a study conducted among adolescents in Los Angeles, California, ever e-cigarette users

were found to be about four times more likely than never e-cigarette users to have initiated marijuana use after two years of follow-up (Audrain-McGovern, Barrington-Trimis, Unger, and Leventhal, 2018).

The evidence of the health consequences of e-cigarette use is also emerging. For example, e-cigarette use or exposure to e-cigarette vapors has been linked to respiratory symptoms in adolescents including hypersensitivity pneumonitis—chemical injury to the lungs (Sommerfeld, Weiner, Nowalk, and Larkin, 2018) and asthma exacerbations (Bayly, Bernat, Porter, and Choi, 2019). Metabolites of carcinogenic chemicals such as acrylonitrile, acrolein, propylene oxide, acrylamide, and crotonaldehyde have been detected, in significant quantities, in urine of adolescent e-cigarette users (Rubinstein, Delucchi, Benowitz, and Ramo, 2018). The potential risks of burn injuries and nicotine poisoning associated with e-cigarette use have also been reported (Brooks et al., 2017; Kumetz et al., 2016).

GUIDING THEORETICAL FRAMEWORKS

Theory of planned behavior

This dissertation was guided by the Theory of Planned Behavior (TPB) which posits that attitudes, subjective norms, and perceived behavioral control, predict behavioral intention, which in turn, predicts behavior (Ajzen 1991; Ajzen and Albarracin, 2007; Ajzen 2012). TPB is based on the premise that intention not only predicts *behavior* but is also the most proximal antecedent to it. It postulates that people's intention to perform a behavior stems from three distinct constructs namely attitudes, subjective norms, and perceived behavioral control ((Ajzen 1991; Ajzen et al., 2007; Ajzen 2012).

Attitudes, subjective norms, and perceived behavioral control are formed from behavioral beliefs, normative beliefs, and control beliefs (Ajzen, 1991; Ajzen et al., 2007; Ajzen 2012), respectively, and are collectively referred to as indirect predictors of behavioral intention (McEachan et al., 2016). It is important to note that the constructs of TPB better predict intention than behavior (Armitage and Conner, 2001; Ajzen 1991; Ajzen et al., 2007; Ajzen 2012).

TPB was selected as the behavioral theory for this dissertation because of its broad narrative framework that captures the pathway from behavioral naivety to actual behavioral performance. TPB explains how initial exposures to risk factors translate to behavior. In addition, its constructs reflect both individual (attitudes, norms, perceived behavioral control) and environmental (control beliefs) factors that contribute to behavioral performance. Existing studies on adolescent e-cigarette use can be grouped under the different constructs of TPB, with majority of studies focusing on background factors (e.g. receptivity to tobacco marketing), attitudes toward e-cigarette use and conventional cigarette smoking (e.g. risk perceptions), and progression to conventional cigarette smoking. TPB can be utilized as a framework around which existing knowledge on adolescent e-cigarette use can be organized to foster our understanding of how e-cigarette use leads to conventional cigarette smoking. Thus, TPB will be an ideal theory for examining the progression from e-cigarette use to conventional cigarette smoking among adolescent never-smokers, and was adopted for use in the current dissertation. The constructs of TPB are discussed below.

Attitudes toward behavior

Attitude toward a behavior is defined as the extent to which a person has a positive or negative evaluation of the behavior under consideration (Azjen, 1991; McEachan et al., 2016). It is formed by accumulated beliefs about the favorable or unpleasant consequences (*behavioral beliefs*) of the behavior (Ajzen, 1991; Ajzen et al., 2007; Ajzen 2012).

Subjective norms

It is defined as perceived social pressure in support of or against the performance of the behavior under consideration (Ajzen, 1991; Ajzen 2012). It is formed by *normative beliefs* about the expectations of relevant groups (peers or parents/guardians) regarding the behavior (Ajzen 1991; Ajzen 2012). Subjective norms comprise both injunctive and descriptive norms (Rimal and Real, 2003; Manning, 2009; McEachan et al., 2016). Injunctive norms are perceptions of the expectations that relevant people (such as friends, family) have concerning the performance of a behavior. It refers to perceptions of whether friends/family approve or disapprove the performance of a behavior (Ajzen, 2012; Fishbein and Ajzen, 2010). Descriptive norms are perceptions of how prevalent the target behavior is among friends and family (Ajzen, 2012; Fishbein and Ajzen, 2010).

Perceived behavioral control (PBC)

PBC is defined as the perception of how easy or difficult it is to perform the target behavior i.e. the perceived capability to perform the behavior (Ajzen, 1991, Ajzen et al., 2007). PBC is formed by beliefs about factors that may facilitate or constrain the ability to perform the target behavior (*control beliefs*) (Ajzen, 1991; Ajzen et al., 2007; Ajzen 2012). People have a high perceived behavioral control over a positive behavior (e.g.

smoking cessation) when they believe lots of opportunities and resources (facilitating factors) are available to perform the behavior and few hindrances (constraining factors) exist (Ajzen, 1991). Conversely, for a negative behavior (e.g. smoking initiation) people have a high perceived behavioral control when they have fewer opportunities and resources to engage in the behavior (e.g. limited access to cigarettes) and more hindrances to the performance of the behavior (e.g. parental monitoring). Access to cigarettes and parental monitoring are control beliefs that may influence smoking intention among adolescents (Bohnert et al., 2009; Spivak et al., 2015, White et al., 2005) and have been included in previous theory-based studies that examined adolescent smoking behavior (Carvajal, Hanson, Downing, Coyle, and Pederson, 2004; Mcmillan and Conner, 2003).

Perceived behavioral control is also considered a proxy for actual control which can also predict behavior (Ajzen et al., 2007; Ajzen 2012). TPB described *actual control* as the ability to perform the target behavior when the opportunity arises (Ajzen et al., 2007; Ajzen 2012). Actual control represents the ability to perform a behavior when the necessary opportunities and resources such as time, money, and cooperation of others are present (Ajzen, 1985), such that when favorable opportunities and resources are available, intention will be more likely to be proceed to actual behavioral performance (Ajzen, 1991).

Behavioral Intention

It is defined as readiness to perform a given behavior, and is considered the immediate antecedent to behavior (Ajzen, 2002). Intention leads to behavior when there

is an adequate degree of actual control (ability to perform the behavior when the necessary opportunities and resources are present) over the behavior (Ajzen, 2002; Ajzen et al., 2007; Ajzen, 2012). Smoking intention has been validated to be a predictor of smoking initiation (Topa and Moriano, 2010). However, in the current literature on adolescent smoking behavior, smoking intention is either used interchangeably with smoking susceptibility (Barrington-Trimis et al., 2016a, Owotomo et al., 2018a), or included as a component of a broader smoking susceptibility index—comprising smoking intention, curiosity, and self-efficacy/behavioral control (Choi et al., 2001; Berry et al., 2019; Pierce et al., 2018; Soneji et al., 2017b; Strong et al., 2015). The smoking susceptibility index is advantageous because it improves the identification of adolescents at risk of initiating smoking (Strong et al., 2015). While the smoking susceptibility index has its advantages, operationalizing smoking intention as "intended" by the TPB may still be needed in studies that aim to investigate smoking intention as a unique behavioral construct or assess its relationships with specific constructs/predictors of adolescent smoking. Such studies provide detailed information on adolescent smoking trajectory.

Intention-behavior relation

Further, TPB explains that perceived behavioral control moderates the relationship between intention and behavior, in a process called *intention-behavior relation* (Ajzen, 2012). Such that intention is a better predictor of behavior when perceived behavioral control is high (Ajzen and Albarracin, 2007). However, of seven studies that tested the hypothesis that behavioral intention and perceived behavioral control should interact to predict behavior (Ajzen, 1991), only one study found a

marginally significant interaction (Schifter & Ajzen, 1985; Ajzen, 1991). In addition, an intention-behavior gap exists between having behavioral intention and actual behavioral performance, and is based on evidence that intention does not always translate to behavior (Sniehotta and Schwarzer, 2005; Sheeran and Webb, 2016). For this dissertation, I adopt the *intention-behavior relation* phrase, as termed by Ajzen (2012) and Sheeran (2002), to explain the relationship between intention to smoke cigarettes and actual smoking initiation.

Background factors

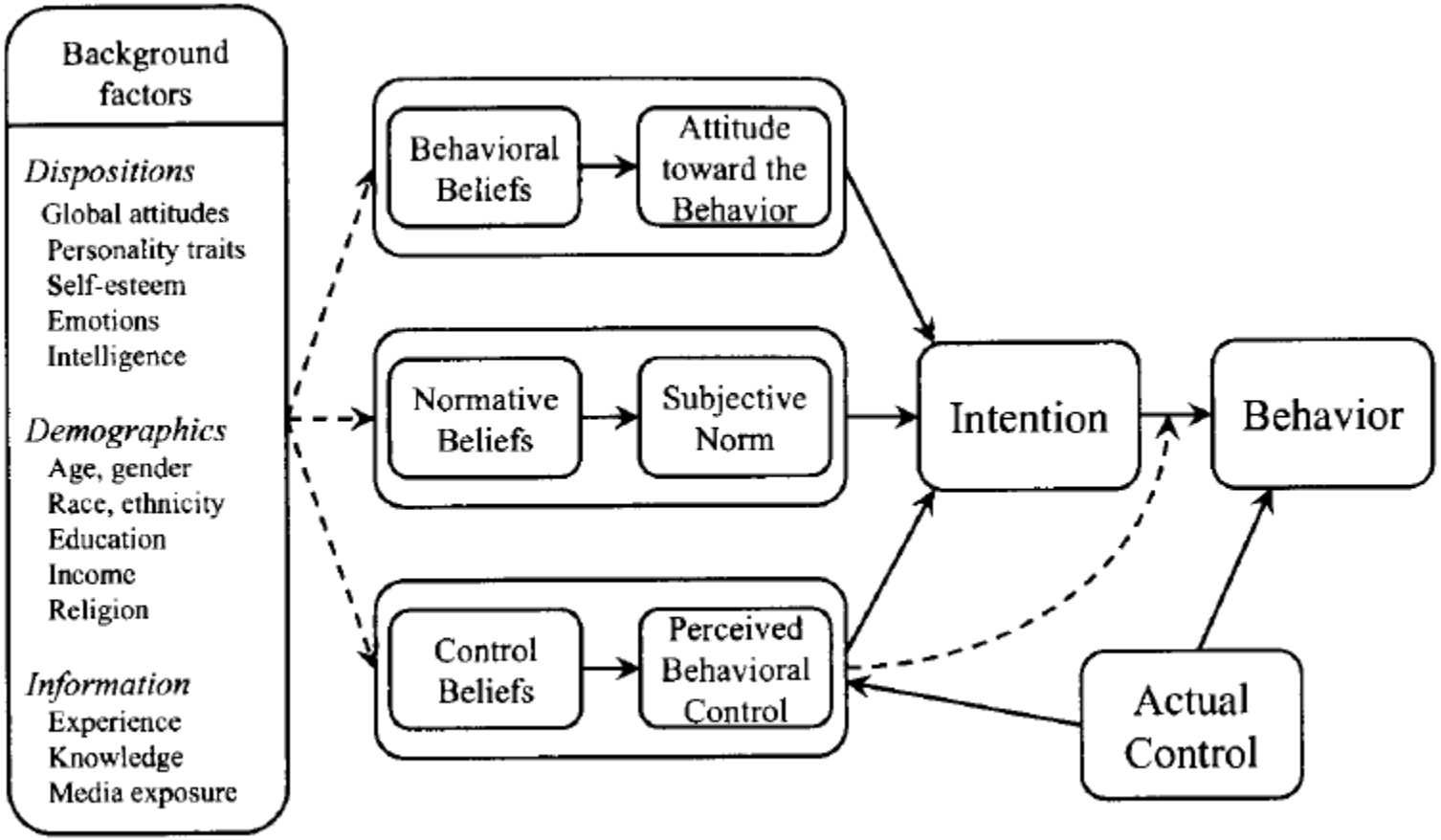
TPB also considers *background factors* that can indirectly predict behavior by influencing behavioral beliefs, normative beliefs, and control beliefs (Ajzen et al., 2007; Ajzen 2012). These background factors are grouped into three categories namely: dispositions (e.g. personality traits, self-esteem, emotions, and intelligence), demographics (age, gender, race/ethnicity, income, education, and religion), and information (experience, knowledge, and media exposure) (Ajzen et al., 2007). It is recommended that the selection of which of the background factors that may influence beliefs concerning a particular behavior should be guided by existing theories within the field of interest (Ajzen et al., 2007). Media exposure (particularly receptivity to pro-tobacco marketing) is an important background factor that has been examined in extant literature on adolescent e-cigarette use (Pierce et al., 2017; Pierce et al., 2018; Pasch et al., 2017). Background factors such as gender, ethnicity, and past behavior can indirectly influence behavioral intention and behavior through beliefs, attitudes, subjective norms, and PBC (Ajzen et al., 2007). They can also influence intention and/or behavior by acting

as moderators of attitudes, subjective norms, and PBC (Ajzen et al., 2007), or as mediators (Ajzen et al., 2007). A recent study conducted by Wills et al (2016a), showed that cognitive and psychosocial factors (such as smoking expectancies) mediated the association between e-cigarette use and conventional cigarette smoking among high school students in Hawaii. Background factors were used primarily as control variables in the current dissertation.

The validity of TPB in predicting health-related behaviors has been tested in several studies (Ajzen et a., 1991; McEachan et al., 2016), including studies that examined adolescent smoking (deVries et al., 1995; Hoie et al., 2011; McMillan et al., 2005; Wilkinson and Abraham, 2004). A meta-analysis conducted to examine if TPB predicts smoking behavior concluded that attitudes, subjective norms, and perceived behavioral control are associated with smoking intention, which in turn, predicts smoking behavior (Topa et al., 2010). Although TPB has been widely used to examine smoking behavior, its use in explaining progression from e-cigarette use to conventional cigarette smoking is limited. As a result, TPB was used in the current dissertation to examine the factors underlying progression from e-cigarette use to conventional cigarette smoking among adolescent never-smokers in the United States.

The Theory of Planned Behavior and its associated constructs are illustrated in Figure 1.1.

Figure 1.1: Theory of Planned Behavior (Ajzen et al., 2007)



CURRENT STATE OF THE LITERATURE

The existing literature on progression from e-cigarette use to conventional cigarette smoking among adolescents in the United States is discussed using the framework provided by the Theory of Planned Behavior (TPB). These studies can be grouped into six major categories: (i) smoking-related background factors of adolescent e-cigarette users; (ii) attitudes of adolescent e-cigarette users toward conventional cigarette smoking; (iii) subjective norms of adolescent e-cigarette users toward conventional cigarette smoking (iv) association between e-cigarette use and smoking intentions; (v) prospective association between e-cigarette use and conventional cigarette smoking; and (vi) link between e-cigarette use and nicotine addiction. Studies that examined perceived behavioral control or control beliefs over conventional cigarette smoking among adolescent e-cigarette users are currently lacking. The studies selected for discussion were either nationally representative or longitudinal in design.

Smoking-related background factors of adolescent e-cigarette users

Smoking-related background factors are defined here as factors that inform attitudes and norms towards conventional cigarette smoking among adolescent e-cigarette users. Generally, in consistence with TPB, these factors have been established to predict conventional cigarette smoking among adolescents and they include exposure to tobacco marketing, personality traits, self-esteem, sensation-seeking/risk-taking propensity, past behaviors, and sociodemographic characteristics (Dube et al., 2013; Sargent et al., 2010; Soneji et al., 2017b; Wilkinson et al., 2004). However, specifically among adolescent e-cigarette users, a unique subpopulation of adolescents, existing literature has focused

primarily on examining the influence of tobacco marketing on intention to smoke conventional cigarettes. For example, a national study, using wave I Population Assessment on Tobacco and Health (PATH) data, found that 12-13 year old e-cigarette users who were receptive to any form of tobacco marketing on TV and print media were more likely to have intention to smoke conventional cigarettes than those who were not (Pierce et al., 2017; Pierce et al., 2018).

Attitudes of e-cigarette users toward conventional cigarette smoking

Of all the TPB constructs, adolescent e-cigarette users' attitudes toward conventional cigarette smoking are the most widely researched in the extant literature. The majority of the studies on adolescent e-cigarette users' smoking-related attitudes have largely focused on examining perceptions of the risk of conventional cigarette smoking relative to e-cigarette use (Ambrose et al 2014; Amrock et al., 2015; Amrock et al., 2016; Wills et al., 2015a).

Perceptions of the risk of conventional cigarette smoking relative to e-cigarette use

Most studies examining adolescent e-cigarette users' perceptions of conventional cigarettes have focused on relative harm perceptions i.e. perception of the harm of e-cigarette use relative to conventional cigarette smoking. Adolescent e-cigarette users have negative attitudes toward conventional cigarette smoking relative to e-cigarette use (Ambrose et al 2014; Amrock et al., 2015; Amrock et al., 2016; Wills et al., 2015a). Most adolescent e-cigarette users believe conventional cigarettes are more harmful and addictive than e-cigarettes. For example, in a national study, current e-cigarette users (compared with non-current e-cigarette users) rated e-cigarettes as less harmful than

conventional cigarettes (73.8% vs 33.1%) (Amrock et al., 2015). Emerging evidence from the few studies that have examined adolescent e-cigarette users' absolute perceptions of harm and addictiveness of conventional cigarettes (product-specific perceptions without comparison to another tobacco product) suggest that adolescent ever e-cigarette users have lower perceptions of harm and addictiveness of conventional cigarettes than never-users of tobacco products (Owotomo, Malsowsky, and Loukas, 2018b [Study 1 of current dissertation]; Strong et al., 2019). See more details below in gaps in literature.

Desensitization of risk perception

E-cigarette use may lead to lowering of initially held perceptions regarding the harm associated with conventional cigarette smoking. Miech et al (2017b) found that adolescent e-cigarette users who progress to conventional cigarette smoking were more likely than non-users to shift away from their initial perceptions that conventional cigarette smoking is dangerous to lower risk perceptions. The study found that e-cigarette use at baseline was associated with a decline in perception of the harm associated with conventional cigarette smoking at follow-up. Indeed, adolescent e-cigarette users (12th graders) were four times more likely than non-users to shift away from their initial (baseline) perception of the great risk associated with conventional cigarette smoking to a perception of low risk at follow-up (Miech et al., 2017b). Thus, e-cigarette use can potentially lower the perception of the harm associated with conventional cigarette smoking, which may in turn, contribute to the progression from e-cigarette use to conventional cigarette smoking.

Subjective norms toward conventional cigarette smoking

Studies that exclusively examined the subjective norms that adolescent e-cigarette users have toward conventional cigarette smoking are very limited. Findings from studies that included subjective norms as covariates while investigating prospective association between e-cigarette use and conventional cigarette smoking among adolescents show that descriptive norms toward conventional cigarette smoking are associated with the progression from e-cigarette use to conventional cigarette smoking (Barrington-Trimis et al., 2016a; Leventhal et al., 2015; Primack et al., 2015). However, studies that specifically examine descriptive and injunctive norms that adolescent e-cigarette users have toward conventional cigarette smoking and how these vary among adolescent e-cigarette users are lacking.

E-cigarette use and smoking intention

E-cigarette use predicts smoking intention among adolescents, such that adolescent e-cigarette users have higher likelihoods of developing smoking intention compared with non-e-cigarette users (Primack et al., 2015). In a national longitudinal study on adolescents and young adults (16-26 years), Primack et al (2015) reported that the odds of progressing from never-smoker to having smoking intention, after a year of follow up, was eight times higher among adolescent e-cigarette users compared with non-e-cigarette users. Wills et al (2015b) also found a direct association between e-cigarette use and willingness to smoke among high school adolescents in Hawaii.

E-cigarette use and conventional cigarette smoking

Adolescent e-cigarette use has been linked to subsequent initiation of conventional cigarette smoking. This is the most researched potential consequence of adolescent e-cigarette use. Several longitudinal studies have demonstrated the prospective association between adolescent e-cigarette use and conventional cigarette smoking (Barrington-Trimis et al., 2016; Berry et al., 2016; Bold et al., 2018; Leventhal et al., 2015; Miech et al., 2017a; Spindle et al., 2017; Unger et al., 2016; Wills et al., 2017). Consistent with prior studies, a most recent national study, Berry et al (2019), found that e-cigarette users were about four times more likely than adolescents who were never-users of tobacco products to have progressed to become ever cigarette smokers after two-year follow up. Evidence also suggests that the association between e-cigarette use and conventional cigarette smoking is unidirectional i.e. e-cigarette use predicts future cigarette smoking but cigarette smoking does not predict future e-cigarette use (Bold et al., 2018). Currently, there is substantial evidence to support a causal effect of e-cigarette use on the transition from never to ever cigarette smoking (NASEM, 2018).

E-cigarette use and nicotine addiction

An association between e-cigarette use and nicotine addiction has also been reported. Most studies linking e-cigarette use to nicotine addiction have been conducted among adults. Such studies found that e-cigarettes could be addictive because they deliver nicotine to the blood (Vansickel et al., 2012; Vansickel et al., 2013). A pattern from experimental to continuous use peculiar to other addictive tobacco products has also been reported for e-cigarette use. Sharapova et al (2018), using combined 2014-2016 National Youth Tobacco Survey (NYTS) data, found that initiating e-cigarettes at an

early age (≤13 years) was associated with continuous daily use. A recent prospective cohort study involving N=181 10th grade students in Los Angeles, California, showed a positive association between nicotine concentration of e-cigarette vaped at baseline and progression to more frequent and intense e-cigarette use and conventional cigarette smoking at follow-up (Goldenson et al., 2017). E-cigarette users who vaped e-cigarettes with high nicotine concentrations (compared with those who vaped e-cigarettes with no nicotine) were seven times more likely to report higher number of cigarettes smoked per day at follow-up. The study provides preliminary evidence of the prospective association between use of e-cigarettes with high nicotine concentration and progression to more established e-cigarette use and conventional cigarette smoking among adolescents.

GAPS IN LITERATURE

Smoking-related background factors of e-cigarette users

Although smoking-related background factors (e.g. exposure to tobacco marketing, personality traits, self-esteem, sensation-seeking, past behaviors, and sociodemographic characteristics), that generally promote conventional cigarette smoking among adolescents have been established (Dube et al., 2013; Sargent et al., 2010; Soneji et al., 2017b; Wilkinson et al., 2004), our knowledge of their role in influencing smoking intentions among adolescent e-cigarette users is largely limited to influence of media exposures (Pierce et al., 2017). Studies on media exposures have particularly focused on exposure to pro-tobacco marketing. However, our knowledge of how adolescent e-cigarette users compare with other adolescent smoking subgroups regarding exposure to anti-tobacco media campaigns is limited. Several studies have established that exposure

to antismoking ads is protective against smoking initiation among adolescents (Farrelly, Davis, Haviland, Messeri, and Healton, 2005; Vallone et al., 2018). Epidemiological surveys have assessed the impact of antismoking ads exposure by asking participants how much they feel they have been influenced by these ads (Johnston, Bachman, O'Malley, Schulenberg, Miech, 2016). Assessing how the perceived influence of antismoking ads vary among adolescents based on tobacco use status and also within same tobacco use-subgroup will be helpful for both intervention development and evaluation purposes. Similarly, sensation-seeking/risk-taking propensity is an important predictor of adolescent smoking behavior (Lydon-Staley and Geier, 2017). A few studies have postulated that adolescent e-cigarette use may be driven by sensation-seeking, which is the same underlying mechanism driving tobacco and other substance use (common liability hypothesis) (Etter, 2018). However, this has been determined unlikely, given recent evidence that suggests a strong association between e-cigarette use and smoking initiation among adolescents classified as having low risk of initiating smoking (Berry et al., 2019; Chapman, Bareham, Maziak, 2018; Wills et al., 2016b). What is yet to be studied is how adolescent e-cigarette users vary from other tobacco-use subgroups regarding risk-taking propensity and whether risk-taking propensity varies within the adolescent e-cigarette user population. Such variations, for example, may be predictive of smoking intention among adolescent e-cigarette users. To this extent, study 1 of the current dissertation (Owotomo et al., 2018b) examined how smoking-related background factors (including perceived low influence of antismoking ads and risk-taking propensity) that could make adolescent e-cigarette users vulnerable to conventional cigarette smoking

differ among e-cigarette users and other tobacco-use subgroups. Study 2 of the current dissertation examined variations in smoking-related background factors (including perceived low influence of antismoking ads and risk-taking propensity) within the adolescent e-cigarette user population and how this may contribute to the identification of a subgroup that is most likely to exhibit smoking intention.

Attitudes of e-cigarette users toward conventional cigarette smoking

The majority of studies that examined attitudes of adolescent e-cigarette users toward conventional cigarette smoking have focused on relative harm perceptions, with a general consensus that adolescent e-cigarette users perceive conventional cigarette smoking to be more harmful than e-cigarette use (Ambrose et al 2014; Amrock et al., 2015; Amrock et al., 2016; Wills et al., 2015a). However, relative risk perceptions in tobacco research provides limited information because it only captures how a tobacco product is perceived in comparison with another tobacco product—conventional cigarettes being the default in most studies (Kaufman, Suls, and Klein, 2016). Indeed, such studies found that e-cigarettes users perceive conventional cigarettes to be more harmful than e-cigarette use. However, results from such studies will vary depending on the referent tobacco product and may lead to misconceptions in the interpretation of findings. For example, if conventional cigarette is the product of reference, any product reported as less harmful than cigarettes may be interpreted as safer by the public and seen as a favored alternative (Kaufman et al., 2016). While information from relative risk evaluation is helpful in understanding adolescents' e-cigarette users' perception of conventional cigarette smoking, it does not provide information on their product-specific

perceptions (Kaufman et al., 2016). Absolute perceptions are product-specific perceptions that capture how a tobacco product is perceived in isolation (without comparing it with another tobacco product) (Popova and Ling, 2013). Absolute perceptions can also provide more insights by shifting the focus of comparison away from the products to the users—by comparing how perceptions of harm and addictiveness of tobacco products differ by user-type. Also, because some adolescents engage in exclusive use of a specific tobacco product, assessing absolute risk perceptions will be helpful in fostering our understanding of their risk perceptions regarding such product (Cooper, Loukas, Case, Marti, and Perry, 2018). Both comparative (relative) and product-specific (absolute) perceptions are needed to fully understand adolescent e-cigarette users' perceptions of harm and addictiveness of conventional cigarette smoking. Understanding perceptions of harm and addictiveness are key to the development of adolescent smoking prevention programs including educational campaigns. While a lot of research has been conducted on relative risk perceptions of conventional cigarettes among adolescent e-cigarette users, only a few studies have looked at absolute risk perceptions. Study 1 of current dissertation (Owotomo et al., 2018b) examined how absolute perceptions of harm and addictiveness of e-cigarette use of adolescent e-cigarette users compare with those non-users, cigarette smokers, and dual users (users of both e-cigarettes and conventional cigarettes). Study 2 of the current dissertation will extend the literature by using a person-centered approach to investigate variations in absolute perceptions of the harm and addictiveness of conventional cigarette smoking within the adolescent e-cigarette user

population and how this may contribute to the identification of a subgroup that is most likely to exhibit smoking intention.

Subjective norms toward conventional cigarette smoking

Studies that specifically examine descriptive and injunctive norms that adolescent e-cigarette users have toward conventional cigarette smoking are lacking. Study 1 of current dissertation (Owotomo et al., 2018b) examined how adolescent e-cigarette users' descriptive norms toward conventional cigarette smoking compare with those of non-users, cigarettes smokers, and dual users. Study 2 of the current dissertation will extend the literature by using a person-centered approach to examine variations in descriptive and injunctive norms within the adolescent e-cigarette user population and how this may contribute to the identification of a subgroup that is most likely to exhibit smoking intention.

E-cigarette use and smoking intention

Although e-cigarette use predicts smoking intention (Barrington-Trimis et al., 2016b; Bunnell et al., 2014; Wills et al., 2015b; Primack et al., 2015), subsets of adolescent e-cigarette users who are most likely to exhibit smoking intentions have not been identified in current literature. As discussed above, most of the smoking-related background factors, attitudes, norms, and control beliefs over conventional cigarette smoking that drive smoking intentions generally among adolescents have not been investigated, specifically, among adolescent e-cigarette users. Also, the majority of existing studies investigating the association between e-cigarette use and smoking intention among US adolescents have used a variable-centered approach to data

analysis—including use of logistic regression models (Bunnell et al., 2014; Wills et al., 2015b; Primack et al., 2015). A person-centered analysis will be more advantageous in examining the relationship between e-cigarette use and smoking intention because it will help classify e-cigarette users into distinct groups based on shared smoking-related characteristics (Jung et al., 2008; Laursen and Hoff 2006). Study 2 will use a person-centered approach to identify subsets of adolescent e-cigarette users that are most likely to have intentions to smoke conventional cigarettes and their smoking-related characteristics.

E-cigarette use and conventional cigarette smoking

Although the prospective association between e-cigarette use and conventional cigarette smoking has been established, the underlying mechanisms on how e-cigarette use results in smoking initiation remain unclear. Some prevailing hypotheses explaining how e-cigarette use may lead to conventional cigarette smoking include the potential addictiveness of nicotine-containing e-cigarettes; similar commercial and social sources for both e-cigarettes and conventional cigarettes; and characteristic smoking techniques that mimic and possibly prime e-cigarette users for conventional cigarette smoking (Schneider and Diehl, 2016). However, existing empirical evidence suggests two major potential underlying mechanisms—an addiction pathway and a smoking intention pathway (Goldenson et al., 2017; Primack et al., 2015). In the addiction pathway, it is suggested that e-cigarettes are capable of delivering nicotine to the blood (Jackler et al., 2019; Vansickel et al., 2012; Vansickel et al., 2013), which may lead to nicotine addiction (Kandel and Kandel, 2014). Nicotine addiction, in turn potentially fuels

continued e-cigarette use and/or future cigarette smoking (Goldenson et al., 2017). Similarly, in the smoking intention pathway, it is suggested that e-cigarette use may lead to smoking intention (Barrington-Trimis et al., 2016b; Wills et al., 2015b; Primack et al., 2015), which is a major antecedent to and strong predictor of smoking initiation among adolescents (Topa et al., 2010). While there is growing evidence on the addiction pathway, our knowledge of the smoking intention pathway is limited to the prospective association between smoking intention and smoking initiation. This dissertation will extend the smoking intention pathway by investigating how e-cigarette use influences the initiation of conventional cigarette smoking beyond the development of smoking intention. For example, the progression from smoking intention to smoking initiation (intention-behavior relation) may be moderated by e-cigarette use (discussed below), such that the association between smoking intention and smoking initiation would be stronger among adolescent e-cigarette users than never e-cigarette users. Thus, this dissertation proposes an intention-behavior moderation pathway as an additional plausible pathway for explaining the progression from e-cigarette use to conventional cigarette smoking.

Intention-behavior relation

Although according to TPB, intention predicts behavior (Ajzen 1991; Ajzen et al., 2007; Ajzen 2012), not all adolescent-never smokers who have smoking intentions end up smoking cigarettes (Bunnell et al., 2014; Wills et al., 2015b et al., 2014; Primack et al., 2015). The intention-behavior relation provides an explanation of the possible factors that may facilitate or hinder progression from intention to behavior (Ajzen et al., 2007;

Ajzen 2012). E-cigarette use may moderate the association between smoking intention and smoking initiation among adolescent never-smokers. Prior studies have established two major findings (i) e-cigarette use predicts smoking intention (Barrington-Trimis et al., 2016b; Wills et al., 2015b; Primack et al., 2015), and (ii) e-cigarette use and smoking intention are strong independent predictors of smoking initiation (Berry et al., 2019; Bold et al., 2018; Topa et al., 2010). However, studies examining interaction between these two smoking predictors are limited. Available evidence suggests that the association between e-cigarette use and smoking initiation is stronger among adolescent who have no prior smoking intention (Barrington-Trimis et al., 2016a). Considering the established strong influence of e-cigarette use on adolescent smoking initiation (Soneji et al., 2017a), one would expect e-cigarette use to also increase the risk of progression from smoking intention to smoking initiation, such that the odds of transitioning from smoking intention to smoking initiation would be higher among e-cigarette users than never e-cigarette users. Study 3 examined whether and how e-cigarette use moderates the association between smoking intention and smoking initiation among adolescent never-smokers of conventional cigarettes.

RESEARCH PURPOSE AND OBJECTIVES

The overall purpose of this dissertation is to use a theory-guided approach to investigate factors that underlie the progression from e-cigarette use to conventional cigarette smoking among adolescent never-smokers of conventional cigarettes. Specifically, this dissertation will:

(i) examine the underlying factors that make adolescent e-cigarette users susceptible to conventional cigarette smoking (study 1),

(ii) identify subgroups of adolescent e-cigarette users most likely to exhibit intention to smoke conventional cigarettes (study 2), and

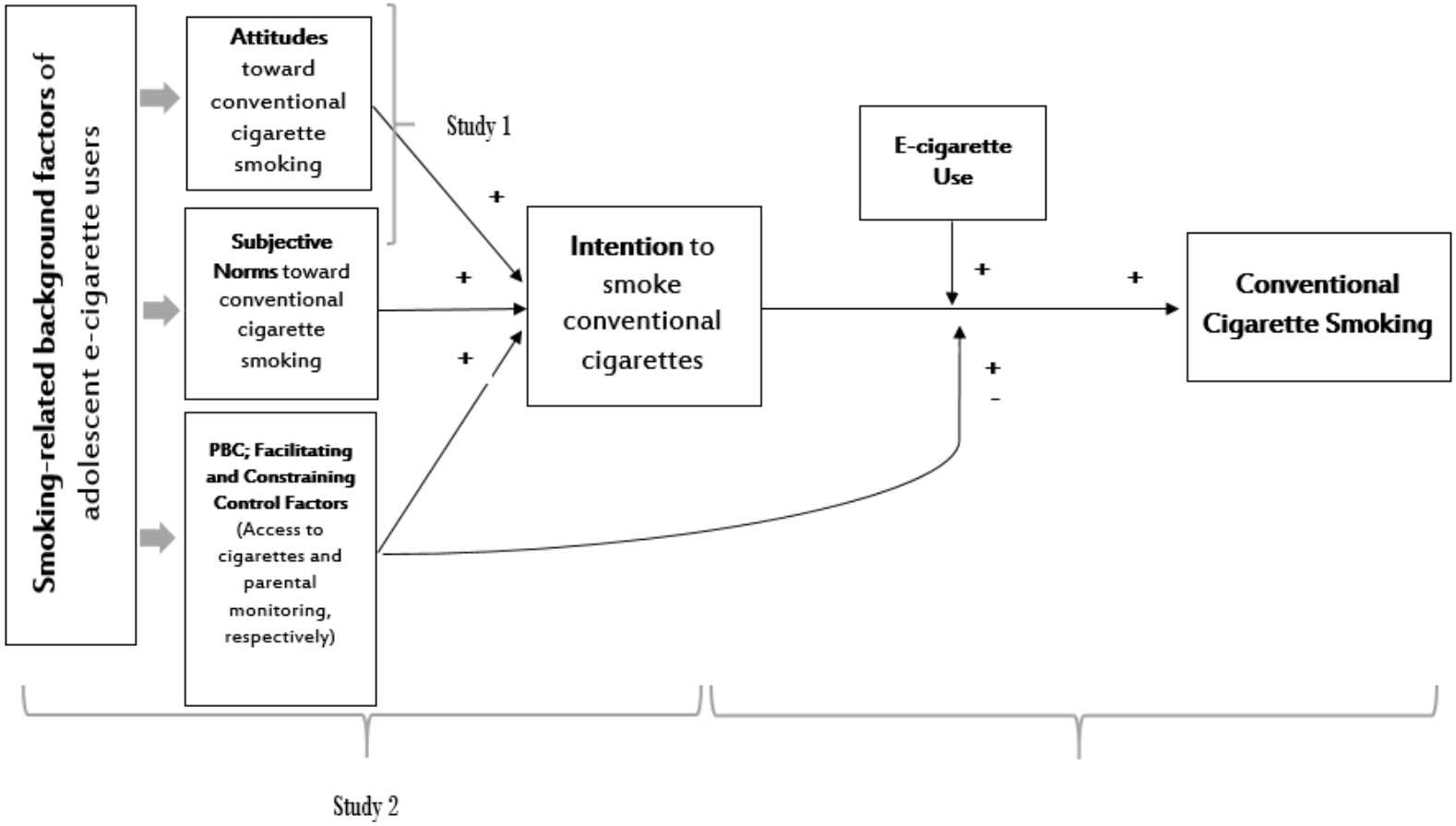
(iii) investigate whether and how e-cigarette use moderates the association between smoking intention and smoking initiation among adolescent never-smokers of conventional cigarettes (study 3).

Conceptual framework

The conceptual framework, which is based on TPB, guiding the proposed studies is depicted in Figure 1.2 and summarized below. Adolescent never-smokers who are current e-cigarette users may have certain background characteristics (e.g. prior exposures to pro-tobacco and anti-tobacco marketing, sensation-seeking/risk-taking propensity, and sociodemographic factors) that predispose them to conventional cigarette smoking. These background characteristics may inform the development of pro-tobacco attitudes, norms, and control beliefs toward smoking, which in-turn, predict intention to smoke conventional cigarettes. Study 1 examines attitudes of e-cigarette users that may make them vulnerable to conventional cigarette smoking. Study 2 classifies adolescent e-cigarette users into subgroups based on their attitudes, norms, and control beliefs (facilitating control belief—access to cigarettes and constraining control belief—parental monitoring) toward smoking, and determines the subgroup that is most likely to exhibit smoking intention. The progression from smoking intention to conventional cigarette smoking may be influenced by several factors including e-cigarette use. Because smoking

intention and e-cigarette use are strong independent predictors of conventional cigarette smoking among adolescents (Primack et al., 2015; Berry et al., 2019), the progression from smoking intention to conventional cigarette smoking may be dependent on e-cigarette status. For example, smoking intention may interact with e-cigarette use to increase the risk of progression to smoking initiation. Study 3 will investigate whether e-cigarette use moderates the association between smoking intention and conventional cigarette smoking among adolescent never-smokers while controlling for perceived behavioral control over smoking, and facilitating and constraining factors, and other potential confounders.

Figure 1.2: Conceptual framework guiding proposed studies



Research questions and hypotheses

The research questions are informed by the gaps in existing literature and guided by the constructs of TPB as discussed above. The three proposed research studies with the adjoining questions and hypotheses are highlighted below:

***Research study 1*:**

Dataset: Monitoring the Future: 8th and 10th grade students, 2014-2015.

Design: Cross-sectional

> **What smoking-related perceptions do adolescent e-cigarette users have that make them susceptible to conventional cigarette smoking?** *I hypothesize that adolescent e-cigarette users will have smoking-related perceptions that are different from non-users but similar to conventional cigarette smokers.*

***Research study 2*:**

Dataset: Monitoring the Future: 8th and 10th grade students, 2014-2016.

Design: Cross-sectional

> **Q2: Are there subgroups of adolescent e-cigarette users that are most likely to exhibit intention to smoke conventional cigarettes?**
>
> **Q2 (a):** Can adolescent e-cigarette users be classified into distinct subgroups using their smoking-related characteristics including background media exposures, attitudes, subjective norms, and control beliefs toward conventional cigarette smoking? *I hypothesize that there will be distinct subgroups of adolescent e-cigarette users based on variations in their smoking-related characteristics.*

Q2 (b): Which adolescent e-cigarette user subgroup is most likely to exhibit intention to smoke conventional cigarettes? *I hypothesize that adolescent e-cigarette user subgroup with the least favorable scores on background media exposures, attitudes, subjective norms, and control beliefs over conventional cigarette smoking will be the most susceptible to conventional cigarette smoking.*

***Research study 3*:**

Dataset & Design: PATH: Age: 12-17 years; Waves 2 and 3 (2014-2016).

Design: Longitudinal.

Q3: Does e-cigarette use moderate the association between smoking intention and smoking initiation among adolescent never-smokers of conventional cigarettes? If so, how? *I hypothesize that e-cigarette use will moderate the prospective association between smoking intention and conventional cigarette smoking among adolescent never-smokers, while controlling for perceived behavioral control, facilitating and constraining control factors and other potential confounders, as guided by TPB. The odds of progressing from smoking intention to smoking initiation would be higher among adolescent e-cigarette users than never e-cigarette users.*

Chapter 2: What smoking-related perceptions do adolescent e-cigarette users have that make them susceptible to conventional cigarette smoking?[1]

INTRODUCTION

Nicotine addiction is an established outcome of conventional cigarette smoking in adolescents (Prokhorov, Pallonen, Fava, Ding, and Niaura, 1996; Stanton, 1995), and may occur even before the onset of daily smoking (DiFranza et al., 2007; Gervais, O'Loughlin, Meshefedjian, Bancej, and Tremblay, 2006). It underlies the progression from cigarette experimentation to sustained smoking, which precipitates smoking-related diseases (Benowitz, 2010). Adolescents may be vulnerable to nicotine addiction because of ongoing brain development (Spear, 2000) and greater brain sensitivity to nicotine (Kandel and Chen, 2000). Nicotine delivered to the brain can impair working memory, attention, executive functioning, and impulse control (deBry and Tiffany, 2008; Galván, Poldrack, Baker, McGlennen, and London, 2011; Jacobsen, Krystal, Mencl, Westerveld, Frost, and Pugh, 2005). Further, adolescents' smoking-related perceptions may influence their smoking behavior, increasing the risk of nicotine addiction. For example, adolescent smokers have poor insight regarding their risk for nicotine addiction and difficulty quitting smoking once addicted (Al-Delaimy, White, and Pierce, 2006; Arnett, 2000; Halpern-Felsher, Biehl, Kropp, and Rubinstein, 2004; Lee and Halpern-Felsher, 2011; Popova and Halpern-Felsher 2016; Roditis, Lee, and Halpern-Felsher, 2016). This

[1] Owotomo, O., Maslowsky, J., & Loukas, A. (2018). Perceptions of the harm and addictiveness of conventional cigarette smoking among adolescent e-cigarette users. *Journal of Adolescent Health, 62*(1), 87–93. https://doi.org/10.1016/j.jadohealth.2017.08.007. Owotomo conceived of the manuscript, conducted analysis, and wrote the initial manuscript draft. All authors contributed to the final manuscript.

suggests the need for research to inform educational interventions that heighten adolescents' perceptions of the addictive potential of all tobacco products including e-cigarettes.

While the prevalence of conventional cigarette smoking has declined over the years, the prevalence of electronic cigarette (e-cigarette) use continues to increase and has surpassed that of conventional cigarette smoking among adolescents (Johnston, O'Malley, Miech, Bachman, and Schulenberg, 2015; Singh et al., 2016). E-cigarettes have become a major source of nicotine to adolescents. The reported use of e-cigarettes in the past 30 days increased from 0.6% in 2011 to 5.3% in 2015 among middle school students and from 1.5% in 2011 to 16% in 2015 among high school students (Singh et al., 2016).

Prior to 2016, the U.S. Food and Drug Administration (FDA) had no regulatory authority over e-cigarettes, and the manufacturing, labeling, distribution, and marketing of e-cigarettes were largely unregulated (FDA, 2016). Although research on the health risks of e-cigarettes is still ongoing, e-cigarettes that contain nicotine have addiction potential because they deliver nicotine to the blood (Vansickel, Weaver, and Eissenberg, 2012; Vansickel and Eissenberg, 2013). In addition, recent studies have demonstrated longitudinal associations between e-cigarette use and conventional cigarette smoking in adolescents, even among the least susceptible, who had no intentions to smoke conventional cigarettes at baseline (Barrington-Trimis et al., 2016a; Primack et al., 2015). Thus, e-cigarette use may facilitate the initiation of conventional cigarette smoking

among adolescents, potentially resulting in nicotine addiction (Dutra and Glantz, 2014; Barrington-Trimis et al., 2016a; Primack et al., 2015; Schneider and Diehl, 2016).

Although existing evidence indicates that e-cigarette use is a risk factor for cigarette smoking initiation, the mechanisms of this association are not yet known. Perceptions of harm and addictiveness of conventional cigarette smoking are important predictors of adolescent smoking behavior, which may differ depending on smoking status and may influence the transition between tobacco products. Previous comparative studies on adolescents' perceptions of harm and addictiveness of cigarette smoking have generated two major findings. First, conventional cigarette smokers acknowledge the physical harm associated with their behavior, but underestimate the risk of nicotine addiction and believe they are less likely to become addicted to nicotine in comparison to the average smoker (Arnett, 2000; Popova et al., 2016; Masiero, Lucchiari, and Pravettoni, 2015; Weinstein Slovic, and Gibson, 2004). This has been referred to as optimistic bias—a perception of one's risk as less than that of others (Helweg-Larsen and Shepperd, 2001). Second, in comparative perceptions of harm and addictiveness of one tobacco product to another, adolescents perceive conventional cigarettes to be more harmful and addictive than e-cigarettes (Ambrose et al., 2014; Amrock et al., 2015; Amrock et al, 2016; Chaffee et al., 2015; Roditis et al., 2015; Roditis et al., 2016). Adolescent e-cigarette users, dual users, and non-users believe e-cigarettes are less harmful than conventional cigarettes (Ambrose et al., 2014; Amrock et al., 2015; Amrock et al, 2016; Chaffee et al., 2015; Roditis et al., 2015; Roditis et al., 2016; Will et al., 2015a). Similarly, adolescent conventional cigarette smokers with a history of e-cigarette

use are more likely than those with no such history to believe e-cigarettes are less harmful than conventional cigarettes (Ambrose et al., 2014).

While the extant literature has generated informative data on adolescents' perceptions of the relative risks of nicotine addiction, studies that specifically examine adolescents' absolute risk perceptions of the addictiveness of conventional cigarette smoking are lacking. In contrast to relative comparisons of one tobacco product to another or comparison of one's own addiction risk to others', absolute risk directly captures adolescents' self-perceptions of addiction and health risks of specific tobacco products. Research on e-cigarette users' absolute risk perceptions of the addictiveness of conventional cigarette smoking is limited. It is important to examine the perceptions that e-cigarette users hold regarding addiction risk of conventional cigarette smoking because it may provide insights into why they use e-cigarettes and whether and how they are vulnerable to initiate conventional cigarette smoking. In addition, comparison of perceptions of the risk of conventional cigarette smoking between e-cigarette only users and dual users (smokers of both conventional cigarettes and e-cigarettes) is warranted. Previous research has documented significant differences between e-cigarette users and dual users in socio-cognitive protective and risk factors, problem behavior risk factors, and use of other substances, indicating that the etiology of nicotine addiction in dual users may differ from that of exclusive e-cigarette or cigarette smokers (Will et al., 2015a). As the popularity of e-cigarettes continues to rise, it is important to understand how e-cigarette users compare with non-users, conventional cigarette smokers, and dual users on absolute perceptions of addiction risk of conventional cigarette smoking, and on

other known predictors of conventional cigarette smoking such as peer smoking, influence of antismoking ads, and risk-taking propensity. Such understanding will help to better characterize the adolescent e-cigarette user population and design effective campaigns to communicate potential harms and addictiveness of e-cigarettes.

In the current study, we examine how e-cigarette users compare to non-users, conventional cigarette smokers, and dual users on smoking-related perceptions in a national sample of 8th and 10th grade students. Specifically, we examine absolute risk perceptions of the addictiveness of conventional cigarette smoking, perceived harm of conventional cigarette smoking, and perceived harm of e-cigarette use. Our study extends the literature by describing e-cigarette users' absolute risk perceptions of the addictiveness and harm of conventional cigarette smoking while accounting for other factors such as sociodemographic variables, peer smoking, perceived influence of antismoking ads, and risk-taking propensity.

Methods

Study Participants

National samples of 8th and 10th grade students from 2014 and 2015 (N = 14,151) were obtained from the Monitoring the Future Study, an annual national cross-sectional survey on adolescent substance use and related behaviors (Miech et al., 2015). Participants were included in the current sample if they were classified as White, Black, or Hispanic race/ethnicity (all other races/ethnicities are combined in the data and therefore uninterpretable) and had non-missing data on both outcome measures, e-cigarette and cigarette use. Data were accessed through the Inter-University Consortium

for Political and Social Research (www.icpsr.umich.edu). This study was exempt from IRB oversight.

Measures

Conventional cigarette smoking was measured via one item: “How frequently have you smoked cigarettes during the past 30 days?” Response was on a 7-point scale ranging from “not at all” to “two packs or more per day” but was dichotomized into any use (1) versus no use (0) for this study.

Similarly, e-cigarette smoking was measured via one item: “During the last 30 days, on how many days (if any) have you used electronic cigarettes (e-cigarettes)?” Response was on a 6-point scale ranging from “none” to “20-30 days” but was dichotomized into any use (1) versus no use (0) for this study.

Absolute perceptions of the addiction risk of conventional cigarette smoking (subsequently referred to as perceived addictiveness of conventional cigarette smoking) were measured using two items: “How much do you agree or disagree with the following statements?” *“I could smoke a pack a day for a year or more and still be able to quit if I wanted to;”* and *“At my age, smoking is not too dangerous because you can always quit later.”* Responses for each measure were on a 5-point scale: "disagree” (1), “mostly disagree” (2), “neither” (3), “mostly agree” (4), and “agree” (5). These items are similar to those used in other studies regarding addiction perceptions among adolescents (Arnett 2000; Masiero et al., 2015; Popova et al., 2016). The two items were reverse coded and averaged for analysis to avoid multicollinearity because they were significantly positively correlated (r = .33, ρ<.001). Higher scores reflected higher perceived addictiveness.

Perceived harm of cigarette smoking was measured via one item: “How much do you think people risk harming themselves (physically or in other ways), if they smoke one or more packs of cigarettes per day?” Responses were on a 4-point scale ranging from “no risk” (1) to “great risk (4).”

Perceived harm of e-cigarette use was similarly measured with cigarettes substituted with e-cigarettes. “How much do you think people risk harming themselves (physically or in other ways), if they use electronic cigarettes (e-cigarettes) regularly?” Responses were on a 4-point scale ranging from “no risk” (1) to “great risk” (4).”

Covariates included perceived influence of antismoking advertisements, peer smoking, risk-taking propensity, class grade (8th or 10th), race/ethnicity, and parent education level. Perceived influence of antismoking advertisements was measured via one item: “To what extent do you think such ads (anti-smoking commercials or "spots" that are intended to discourage cigarette smoking) on TV, radio, billboards or in magazines and newspapers have made you less favorable toward smoking cigarettes?” Responses were on a 5-point scale ranging from "not at all (1)" to "to a very great extent (5)."

Peer smoking was measured via one item: “How many of your friends would you estimate smoke cigarettes?” Responses were on a 5-point scale ranging from "None" (1) to "All" (5).

Risk-taking propensity was measured by obtaining the average of two items: “I get a real kick out of doing things that are a little dangerous” and “I like to test myself

every now and then by doing something a little risky." Each of the two items had responses on a 5-point scale ranging from "Disagree" (1) to "Agree" (5).

Race/ethnicity was categorized into (non-Hispanic) White, Hispanic, and (non-Hispanic) Black.

Parent education level, selected as an indicator of socioeconomic status (SES), was measured with a 6-point scale ranging from "completing grade school or less" to "graduate or professional school after college." The average of both parent education levels (single parent's education level was used for students with single parents) was determined.

Data analysis

Adolescents were classified into one of four smoking status groups: non-users (had not smoked cigarettes or used e-cigarettes in the past 30 days); conventional cigarette smokers (smoked only cigarettes in the past 30 days); e-cigarettes users (used only e-cigarettes in the past 30 days), and dual users (smoked conventional cigarettes and used e-cigarettes in the past 30 days).

Independent samples t-tests were used to test mean differences in smoking-related perceptions across the four smoking groups. Multivariate logistic regression was used to examine the relationships between perceptions of addiction and harm of conventional cigarette smoking, perceived harm of e-cigarette use, perceived influence of antismoking ads, and adolescent smoking status, while controlling for risk-taking propensity, peer smoking, and sociodemographic variables. Three models were tested, such that for each model, e-cigarette users were compared to a referent smoking status; (1) e-cigarette users

versus non-users, (2) e-cigarette users versus conventional cigarette smokers, and (3) e-cigarette users versus dual users. Univariate pairwise comparisons were conducted using SPSS Complex samples, version 24, and multivariate analysis was conducted using Mplus version 7 (Muthén and Muthén, 2012). Full information maximum likelihood (FIML) was used to account for missing data on independent variables. MTF sampling weights were applied in all analyses (Miech et al., 2015).

Results

85.5% of participants were non-users, 9.1% e-cigarette users, 3.3% dual users, and 2.1% cigarette smokers. Descriptive statistics are summarized in Table 2.1.

Table 2.1: Sample descriptive statistics, *N* = 14,151

		%
Sex		
	Male	49.0
	Female	51.0
Grade		
	Eighth	48.5
	Tenth	51.5
Race/Ethnicity		
	White	64.3
	Hispanic	21.2
	Black	14.5
Smoking Status		
	E-cigarette users	9.1
	Cigarettes smokers	2.1
	Dual Users	3.3
	Non-Users	85.5

Smoking-related perceptions differed by adolescent smoking status in univariate comparisons across groups (Table 2.2). The four smoking groups differed significantly in perceived addictiveness and perceived harm of conventional cigarette smoking, with scores highest among non-users, intermediate among e-cigarette users, and least among conventional cigarette smokers and dual users. Also, e-cigarette users differed significantly from non-users and conventional cigarette smokers on perceived harm of e-cigarette use, with non-users scoring highest, conventional cigarette smokers and dual users intermediate, and e-cigarette users least.

Results of the multivariate logistic regressions are summarized in Table 2.3. Compared to non-users, e-cigarette users had lower perceived addictiveness of conventional cigarette smoking and lower perceived harm of e-cigarette use (Model 1). E-cigarette users also reported less influence by antismoking ads, higher risk-taking propensity, and more cigarette-smoking friends than non-users.

Compared to conventional cigarette smokers, e-cigarette smokers had higher perceived addictiveness of conventional cigarette smoking and lower perceived harm of e-cigarette use (Model 2). E-cigarette users reported they were more influenced by antismoking ads and had fewer cigarette-smoking friends than cigarette smokers. Notably, e-cigarette users did not significantly differ from cigarette smokers with regards to perceived harm of conventional cigarette smoking or risk-taking propensity, both known risk factors for conventional cigarette smoking.

Compared to dual users, e-cigarette users reported higher perceived addictiveness of conventional cigarette smoking and higher perceived harm of conventional cigarette

smoking. E-cigarette users also reported more influence by antismoking ads, and fewer cigarette-smoking friends than dual users. E-cigarette users did not differ from dual users in their perceptions of the harm associated with e-cigarette use.

Table 2.2: Adolescents' smoking-related perceptions by smoking status (N = 14,151)

	Non-users	E-cigarette Users	Conventional Cigarette Smokers	Dual Users
	M (SD)	*M* (SD)	*M* (SD)	*M* (SD)
Perceived addictiveness of conventional cigarette smoking	4.38 (0.92)[b, c, d]	4.10 (1.10)[a, c, d]	3.69 (1.14)[a, b]	3.56 (1.27)[a, b]
Perceived harm associated with conventional cigarette smoking	3.60 (0.95)[b, c, d]	3.51 (1.03)[a, c, d]	3.34 (1.06)[a, b]	3.25 (1.08)[a, b]
Perceived harm associated with e-cigarette use	2.37 (1.04)[b, c, d]	1.83 (0.90)[a, c]	1.98 (0.94)[a, b, d]	1.74 (0.92)[a, c]

Higher scores on the variables indicate higher perceived addictiveness of conventional cigarette smoking, higher perceived harm, and higher perceived influence of antismoking ads. Non-users are defined as non-e-cigarette users and non-conventional cigarette smokers.
Independent samples t-tests were used to compare the means of smoking-related perceptions across smoking groups. Superscripts a, b, c, d denote significant mean differences across smoking groups ($p<.05$)—a. differed significantly from non-users; b. differed significantly from e-cigarette users; c. differed significantly from conventional cigarette smokers; d. differed significantly from dual users.

Table 2.3: Multivariate binary logistic regression: e-cigarettes users' perceptions of the addiction and harm risks of conventional cigarette smoking (N = 14,151)

	Model 1 E-cigarette Users vs Non-users			Model 2 E-cigarette Users vs Cigarette Smokers			Model 3 E-cigarette Users vs Dual Users		
	B (SE)	OR	95% CI	B (SE)	OR	95% CI	B (SE)	OR	95% CI
Perceived addictiveness of conventional cigarette smoking	-0.09 (0.04)	0.91*	0.85 – 0.98	0.21 (0.06)	1.24**	1.09 – 1.40	0.29 (0.06)	1.33***	1.18 – 1.50
Perceived harm of conventional cigarette smoking	0.06 (0.04)	1.06	0.97 – 1.15	0.09 (0.08)	1.09	0.94 – 1.27	0.15 (0.07)	1.16*	1.01 – 1.34
Perceived harm of e-cigarette use	-0.46 (0.05)	0.63***	0.58 – 0.69	-0.34 (0.08)	0.71***	0.61 – 0.84	-0.08 (0.09)	0.92	0.78 – 1.09
Perceived influence of anti-smoking ads	-0.06 (0.03)	0.95*	0.90 – 0.99	0.45 (0.06)	1.57***	1.41 – 1.74	0.38 (0.05)	1.46***	1.32 – 1.63
Peer smoking	0.32 (0.04)	1.38***	1.28 – 1.49	-0.57 (0.08)	0.57***	0.49 – 0.66	-0.84 (0.07)	0.43***	0.38 – 0.50
Risk-taking propensity	0.27 (0.03)	1.31***	1.24 – 1.39	0.07 (0.07)	1.07	0.93 – 1.24	-0.10 (0.06)	0.90	0.80 – 1.02
Sex (Reference = Male)	-0.26 (0.07)	0.77***	0.67 – 0.89	-0.60 (0.16)	0.55***	0.40 – 0.75	-0.36 (0.14)	0.70*	0.53 – 0.92
Grade (Reference = 8)	0.23 (0.04)	1.26***	1.17 – 1.36	0.16 (0.08)	1.18	1.00 – 1.39	0.12 (0.08)	1.12	0.97 – 1.31
Race/ethnicity (Reference = White)									
Black	-0.47 (0.12)	0.63***	0.50 – 0.80	-0.28 (0.25)	0.76	0.47 – 1.23	0.77 (0.27)	2.17**	1.27 – 3.71
Hispanic	0.26 (0.09)	1.29**	1.08 – 1.55	0.71 (0.21)	2.02**	1.35 – 3.03	0.79 (0.19)	2.20***	1.52 – 3.19
Parent Education	0.00 (0.03)	1.00	0.94 – 1.07	0.19 (0.07)	1.21**	1.05 – 1.38	0.10 (0.06)	1.11	0.99 – 1.25

****p<.001; **p<.01; *p<.05; OR: Odds Ratio; CI: Confidence Interval. SE: Standard Error.*

Higher scores on the variables indicate higher perceived addictiveness of conventional cigarette smoking, higher perceived harm, higher perceived influence of antismoking ads, higher risk-taking propensity, higher peer smoking, and higher parent education level.

Discussion

The current study revealed systematic differences in e-cigarette users' perceptions of addiction and harm of conventional cigarette smoking compared to those of non-users, conventional cigarette smokers, and dual users. Differences in e-cigarette users' attitudes and perceptions regarding conventional cigarette smoking (compared to those of non-users) and similarities to conventional cigarette smokers may leave them vulnerable to becoming conventional cigarette smokers or dual users in the future, potentially increasing their risk for nicotine addiction.

Compared to non-users, e-cigarette users endorsed a number of attitudes, perceptions, and characteristics that are risk factors for cigarette smoking. First, they had lower perceptions of the addictiveness of conventional cigarette smoking, including greater optimism about their ability to quit conventional cigarette smoking in the future. Previous comparative studies have shown that adolescents generally believe conventional cigarettes smoking is more harmful and addictive than e-cigarette use (Ambrose et al., 2014; Amrock et al., 2015; Amrock et al, 2016; Chaffee et al., 2015; Roditis et al., 2015; Roditis et al., 2016). The current study extends this literature by examining e-cigarette users' absolute risk perceptions of the addictiveness of conventional cigarette smoking without comparing it to e-cigarette use. Our results suggest e-cigarette users' perception of the addictiveness of conventional cigarette smoking is weaker than that of non-users. Second, e-cigarette users had higher levels of risk propensity and more peers who smoke cigarettes, both robust risk factors for cigarette smoking (Burt, Dinh, Peterson, and Sarason, 2000; Chassin, Presson, Sherman, Montell, and McGrew, 1986). Finally,

compared to non-users, e-cigarette users reported less influence by antismoking ads. Non-responsivity to anti-smoking ads is another known risk factor for conventional cigarette smoking (Farrelly et al., 2005) and may be an avenue by which e-cigarette smokers are vulnerable to becoming conventional cigarette smokers.

E-cigarette users also differed from cigarette smokers and dual users on several key variables. On several variables known to be risk factors for conventional cigarette smoking, e-cigarette users appeared relatively low-risk. E-cigarette users had higher addiction perceptions of conventional cigarette smoking, indicating less optimism about their ability to quit conventional cigarette smoking in the future, compared to both cigarette smokers and dual users. E-cigarette users perceived conventional cigarette smoking to be more harmful than dual users. They also reported that they had been more influenced by antismoking ads than both cigarette smokers and dual users.

However, on several other known risk factors for conventional cigarette smoking, e-cigarette users were comparable to or worse than cigarette smokers and/or dual users. E-cigarette users perceived e-cigarettes as less harmful than did cigarette smokers. Their perceptions of harm of conventional cigarette smoking did not differ from those of cigarette smokers. E-cigarette users also had comparable levels of risk-taking propensity to cigarette smokers and dual users, which may put them at further risk for later cigarette smoking.

In summary, our results yield a profile of e-cigarette users that shows they are quite distinguishable from non-users on an array of risk factors for conventional cigarette smoking. While they differ from cigarette smokers and dual users in some positive

regards, e-cigarette users are overall more similar to cigarette smokers and dual users with regards to their perceived addictiveness and harm of smoking than they are to non-users. These perceptions may put them at risk for future conventional cigarette smoking.

Past research has shown e-cigarette smokers to be at heightened risk for later cigarette smoking (Dutra and Glantz, 2014; Barrington-Trimis et al., 2016a; Primack et al., 2015; Schneider and Diehl, 2016). Our study adds to this literature by revealing perceptions that may make adolescent e-cigarette users vulnerable to initiating conventional cigarette smoking. Specifically, we found that optimism regarding quitting smoking in the future, previously demonstrated among adolescent cigarette smokers, also exists among adolescent e-cigarette users and is demonstrable even without subjective comparisons to the average smoker as reported in prior comparative studies (Arnett, 2000; Masiero et al., 2015; Popova et al., 2016; Weinstein et al., 2004). We established that e-cigarette users (compared to non-users) are more optimistic about ease of quitting smoking in the future, have more peers who smoke cigarettes, have higher risk-taking propensity, and have been less influenced by antismoking ads. Also, e-cigarette users share similar harm perceptions of conventional cigarette smoking with cigarette smokers, and similar risk-taking propensity with cigarette smokers and dual users. The effect of these perceptions on the transition from e-cigarette use to conventional cigarette smoking should be further explored in longitudinal studies.

Our study has some limitations. First, our e-cigarette and cigarette use variables were measured via self-report, and addiction-related variables were measured via a few items, though notably these items are similar to those used in previous studies (Arnett,

2000; Halpern_Felsher et al., 2004; Masiero et al., 2015; Popova et al., 2016). Second, the dataset lacks a measure of the perceived addictiveness of e-cigarettes, the addition of which will be a crucial next step for future research. Further, causal inferences cannot be made from our findings due to the cross-sectional nature of this study. However, our large, national sample makes our findings generalizable to the White, Black, and Hispanic 8th and 10th grade adolescent population in the United States.

In conclusion, e-cigarette users have muted perceptions of the addictiveness of conventional cigarette smoking compared to non-users, and they perceive e-cigarette use to be less harmful than all other groups except dual users. Adolescent e-cigarette users may be vulnerable to initiating conventional cigarette smoking due to these muted addiction perceptions and due to their similarity to cigarette smokers and dual users on such risk factors as risk taking propensity and friends who smoke cigarettes. Future research should include the development of measures that specifically assess perceived risks of nicotine addiction associated with new tobacco products including e-cigarettes. Further, longitudinal studies are needed to assess the prospective relationship between smoking-related perceptions of conventional cigarette smoking among e-cigarette users and onset of conventional cigarette smoking, in order to extend upon the cross-sectional results presented here. Practically, antismoking messages should be expanded to address the potential addiction risks associated with all tobacco products, not just conventional cigarettes.

Chapter 3: Are there subgroups of adolescent e-cigarette users that are more likely to exhibit intention to smoke conventional cigarettes?

INTRODUCTION

Conventional cigarette smoking remains a major cause of significant morbidity and mortality in the United States. Because the majority (over 90%) of adults smokers initiate smoking during adolescence (USDHHS, 2014), preventing smoking initiation among adolescents is pivotal to the reduction of tobacco-related diseases and deaths. Although adolescent smoking rates have declined significantly over the past few decades, from 28.3% in 1996 to 4.6% in 2018 (Johnston, Miech, O'Malley, Bachman, Schulenberg, and Patrick, 2019), disparities remain with rates as high as 14.4% among high school students in West Virginia and 10.3% among American-Indian/Alaskan Native adolescents (CDC, 2018a; Odani et al., 2018). Also, the emergence of new tobacco products such as e-cigarettes constitute newer threats that can potentially reverse the current declines in adolescent smoking rates (USDHHS, 2016). Currently, e-cigarettes have become more popular than conventional cigarettes and they serve as newer sources (particularly the highly addictive types, such as JUUL) of nicotine to adolescents (USDHHS, 2018a). Adolescents are particularly vulnerable to nicotine addiction because of ongoing brain development (Kandel and Chen, 2000; Spear, 2000). Adolescent e-cigarette users who progress to conventional cigarette smoking or who use both e-cigarettes and conventional cigarettes are even at higher risk of nicotine exposures and addiction. Thus, the rising prevalence of adolescent e-cigarette use together with the associated risks of nicotine addiction and progression to conventional cigarette smoking

are emerging public health issues warranting immediate intervention (FDA, 2018). In the span of one year (2017-2018), reported prevalence of e-cigarette use increased by 78% (11.7% to 20.8%) among high school students and by 49% (3.3% to 4.9%) among middle school students (Gentzke et al., 2019). Currently, there is substantial evidence to support a causal effect of e-cigarette use on the transition from never to ever cigarette smoking among adolescents (NASEM, 2018).

Although adolescents who use e-cigarettes are at heightened risk of progressing to initiate conventional cigarette smoking (Barrington-Trimis et al., 2016a; Leventhal et al., 2015; Miech et al., 2017a; Primack et al., 2015; Soneji et al., 2017a; Unger et al., 2016; Wills et al., 2017), the factors underlying this progression remain unclear. As predicted by the Theory of Planned Behavior (TPB), intention is the most proximal antecedent to behavior (Ajzen et al., 2007; Ajzen, 2012), accordingly, smoking intention predicts smoking initiation (deVries et al., 1995; Pierce et al., 1996). Recent studies have established e-cigarette use as a major predictor of smoking intention among adolescents (Bunnell et al., 2014; Wills et al., 2015b; Primack et al., 2015, Owotomo and Maslowsky, 2018a). A sizeable proportion (43.9%) of adolescent never-smokers who had ever used an e-cigarette reported having intention to smoke conventional cigarettes in the near future (Bunnell et al., 2014). In a recent national longitudinal study, over 31% of adolescent e-cigarette users progressed to develop smoking intentions after one year of follow-up, and e-cigarette users (compared with never e-cigarette users) who had no smoking intention at baseline were about eight times more likely to progress to have smoking intention after one year of follow-up (Primack et al., 2015). Based on TPB,

adolescent e-cigarette users who develop smoking intention are at risk of initiating conventional cigarette smoking. Thus, characterizing the adolescent e-cigarette user subpopulation based on their likelihood to exhibit smoking intention will be instructive in developing targeted smoking prevention interventions.

In general, the factors influencing smoking intention among adolescents have been widely reported in the existing literature. Negative attitudes and norms toward smoking, exposure to tobacco marketing, and lack of effective tobacco control policies are known predictors of smoking intention among adolescents (USDHHS, 2014). Knowledge of these factors has led to development of smoking prevention programs that have been instrumental to the decline in adolescent smoking prevalence in the past few decades (USDHHS, 2014). However, with the changing tobacco landscape—characterized by increasing popularity of e-cigarettes and its associated risk of influencing progression to conventional cigarette smoking—research focused on investigating the unique smoking-related characteristics of adolescent e-cigarette users is warranted. Compared to the general adolescent population, adolescent e-cigarette users are uniquely vulnerable to smoking—because in addition to being exposed to the historically known risk factors of smoking, e-cigarette use may confer an additional layer of risk that further predisposes them to smoking intention and initiation.

Scientific literature on the factors influencing smoking intention specifically among adolescent e-cigarette users who have never smoked conventional cigarettes is still emerging. The few existing studies have largely focused on how known risk factors of smoking behavior such as low risk perceptions and/or exposure to tobacco marketing

may make adolescent e-cigarette users vulnerable to conventional cigarette smoking (Ambrose et al 2014; Amrock et al., 2015; Amrock et al., 2016; Owotomo and Maslowsky, 2018b; Pierce et al., 2017; Pierce et al., 2018). Also, existing studies have been variable-centered in their approach to data analyses—examining how e-cigarette use or predictors of e-cigarette use influence smoking behavior among adolescents—as opposed to a person-centered approach that utilizes variable information to identify clusters of adolescent e-cigarette users (Jung and Wickrama, 2008; Laursen and Hoff 2006). Identifying clusters of adolescent e-cigarette users will provide detailed information on how their unique characteristics combine to put them at risk of exhibiting smoking intention. In the current study, I propose a theory-guided variable selection for the prediction of smoking intention among adolescent e-cigarette users; and favor a person-centered approach to data analysis that aims to identify subgroups of adolescent e-cigarette users based on their performance on theoretically selected smoking–related variables.

Theory of Planned Behavior

According to TPB, the predictors of behavioral intention are background characteristics and exposures, attitudes toward the behavior, subjective norms about the behavior, and perceived behavioral control (Ajzen, 1991; Ajzen et al., 2007; Ajzen, 2012). The ensuing paragraphs will summarize the existing literature on adolescent e-cigarette users' smoking-related background factors, attitudes toward conventional cigarette smoking, subjective norms (descriptive and injunctive norms) regarding

conventional cigarette smoking, and perceived behavioral control over conventional cigarette smoking.

Smoking-related background factors

In the current study, smoking-related background factors are defined as prior exposures and inherent or deep-rooted characteristics of adolescents that precede the development of smoking intention. These factors which inform attitudes and norms concerning conventional cigarette smoking include pro- and anti-tobacco media exposures, sociodemographic characteristics (race/ethnicity, age, socioeconomic status--SES), and risk-taking propensity. (Dube et al., 2013; Farrelly et al., 2005; Sargent et al., 2010; Soneji et al., 2017b). Research on how smoking-related background factors influence smoking intention specifically among adolescent e-cigarette users is limited. The few studies, which are variable-centered in approach, have focused on the role of tobacco marketing in predicting smoking intention among adolescent e-cigarette users. For example, receptivity to tobacco marketing is associated with intention to smoke conventional cigarettes among adolescent e-cigarette users (Pierce et al., 2017; Pierce et al., 2018)—which is in keeping with what is already known about the predictors of smoking intention in the general adolescent population (Dube et al., 2013; Soneji et al., 2017b). However, what is yet to be reported is whether or not clusters of adolescent e-cigarette users exist who are similar in their smoking-related background factors and how this may inform the identification of subgroups at most risk of having smoking intention. Similarly, risk-taking propensity is an important predictor of adolescent smoking behavior (Lydon-Staley and Geier, 2017). Etter et al (2018) suggest that adolescent e-

cigarette use may be driven by risk-taking propensity—through the same underlying mechanism driving tobacco and other substance use (common liability hypothesis). This is however unlikely given recent evidence that suggests a strong association between e-cigarette use and smoking initiation among adolescents classified low risk for smoking initiation (Berry et al., 2019; Chapman, Bareham, Maziak, 2018; Wills et al., 2016b). What remains unknown is whether risk-taking propensity varies within the adolescent e-cigarette user population, and how such variations may be predictive of smoking intention. Sociodemographic characteristics (race/ethnicity, age, socioeconomic status--SES) of adolescent e-cigarettes users may also influence their intention to smoke cigarettes, thus, they were adequately controlled for in the current study.

Attitudes toward conventional cigarette smoking

Generally, attitudes predict behavioral intention (Ajzen et al., 2007; Ajzen, 2012), such that smoking intention among adolescents is often determined by their perceptions of conventional cigarette smoking. Adolescents who perceive conventional cigarette smoking to be harmful and addictive are less likely to have smoking intention (Halpern-Felsher, Biehl, Kropp, and Rubinstein, 2004). In the current tobacco landscape, our knowledge of adolescent e-cigarette users' attitude toward conventional cigarette smoking is limited to their perception of the harm of conventional cigarette smoking relative to e-cigarette use (Ambrose et al 2014; Amrock et al., 2015; Amrock et al., 2016; Wills et al., 2015a). Adolescent e-cigarette users perceive conventional cigarette smoking to be more harmful than e-cigarette use (Ambrose et al 2014; Amrock et al., 2015; Amrock et al., 2016; Wills et al., 2015a). This is likely a reflection of how e-cigarettes

have been historically presented and marketed to the overall population—with e-cigarette companies marketing their products as safer alternatives to conventional cigarettes or as smoking cessation aids. While we have insights on how adolescent e-cigarette users rate the harm and safety of e-cigarette use relative to conventional cigarette smoking, little is known about how adolescent e-cigarette users specifically perceive conventional cigarette smoking without comparing it to e-cigarette use. Absolute perceptions are product-specific perceptions that capture how a tobacco product is perceived in isolation (without comparing it with another tobacco product) (Cooper et al., 2018; Kaufman et al., 2016; Popova and Ling, 2013). Absolute perceptions can also provide more insights by shifting the focus of comparison away from the products to the users, for example, comparing how perceptions of harm and addictiveness of tobacco products differ between and/or within user-type. Also, because adolescent e-cigarette users are at risk of progressing to conventional cigarette smoking, assessing absolute risk perceptions will foster our understanding of their risk perceptions regarding conventional cigarette smoking—an important first step in understanding the underlying factors involved in the progression from e-cigarette use to conventional cigarette smoking. Emerging evidence from recent studies suggests that compared to non-users of tobacco products, e-cigarette users have lower perceptions regarding the harm and addictiveness of conventional cigarette smoking, which may increase their risk of becoming conventional cigarette smokers (Strong et al., 2019; Owotomo et al., 2018b). However, what remains unknown is whether adolescent e-cigarette users vary in their absolute perceptions of harm and addictiveness of conventional cigarette smoking and how this may be useful in

classifying them into subgroups to determine the subgroup most likely to have smoking intention.

Subjective norms toward conventional cigarette smoking

Subjective norms are defined here as adolescents' perceptions of the social pressure in support of or against conventional cigarette smoking (Ajzen, 1991; Ajzen 2012). They refer to perceptions of whether friends and/or family approve or disapprove of conventional cigarette smoking (injunctive norms; Ajzen, 2012; Fishbein and Ajzen, 2010) and perceptions of how prevalent conventional cigarette smoking is among friends and/or family (descriptive norms; Ajzen, 2012; Fishbein and Ajzen, 2010). Peer smoking (descriptive norm) and friends' approval of smoking are strong predictors of adolescent smoking behavior (Gritz et al., 2003; Johnston et al., 2019). However, our knowledge of the injunctive and descriptive norms that adolescent e-cigarette users have concerning conventional cigarette smoking is limited. Barrington-Trimis et al (2016a) included both injunctive and descriptive norms as covariates while investigating prospective association between e-cigarette use and conventional cigarette smoking among adolescents. The study findings suggest that while descriptive norm (having friends or parents who smoke cigarettes) was associated with progression from e-cigarette use to smoking initiation, injunctive norm (friends' approval of smoking) was not associated (Barrington-Trimis et al., 2016a). Other studies with similar objectives adjusted for only descriptive norms (Leventhal et al., 2015; Primack et al., 2015), and found that having friends who smoke conventional cigarettes is associated with progression from being non-susceptible to smoking to smoking initiation among adolescent never-smokers followed for a year

period (Primack et al., 2015). More studies that specifically examine how adolescent e-cigarette users' descriptive and injunctive norms toward conventional cigarette smoking influence smoking intention, as implied by the TPB, are warranted. According to TPB, subjective norm is a major predictor of smoking intention, and it is recommended that studies guided by TPB examine both injunctive and descriptive norms for complete information on the perceived social pressure in support of or against the target behavior (Rivis and Sheeran, 2003). Thus, investigating adolescent e-cigarette users' descriptive and injunctive norms toward conventional cigarette smoking will be helpful in identifying the subset that is most likely to have smoking intention.

Perceived behavioral control over conventional cigarette smoking

PBC over conventional cigarette smoking is the perception of how easy or difficult it is to initiate smoking (Ajzen, 1991, Ajzen et al., 2007). It is formed by control beliefs (beliefs about factors that can facilitate or constrain the performance of a behavior) (Ajzen 1991; Ajzen et al., 2007; Ajzen 2012). PBC can be assessed either directly—by asking questions about the capability to perform the behavior or indirectly—by using belief-based measures that are related to one's ability to navigate specific facilitating or constraining factors surrounding the behavior (Ajzen, 2002). Generally, adolescents' PBC over conventional cigarette smoking has been scarcely reported in the existing literature, which may be due to a lack of consensus on the measures and operationalization of perceived behavioral control (Topa et al., 2010). However, based on the premise that PBC is indeed formed by control beliefs/factors (Azjen, 2002), belief-based measures are advantageous because they provide additional insights on the origins

or cognitive foundations underlying PBC (Ajzen, 2002). Thus, investigating control beliefs or factors that either make it easier or more difficult for adolescent e-cigarette users to initiate smoking will be instructive in understanding why they progress to conventional cigarette smoking. Control beliefs/factors such as access to cigarettes and parental monitoring, which are established predictors of smoking intention in the general adolescent population (Bohnert et al., 2009; Forrester, Biglan, Severson, and Smolkowski, 2007; Spivak et al., 2015, White et al., 2005), may also facilitate or hinder the development of smoking intention among adolescent e-cigarette users. Classifying adolescent e-cigarette users based on their exposures to factors that facilitate or hinder conventional cigarette smoking will provide additional insights into their risks of developing smoking intention.

Person-centered approach versus variable-centered approach

A variable centered-approach to analysis describes relationships between variables by providing information on which variables predict an outcome of interest (Jung et al., 2008; Laursen and Hoff 2006). The majority of existing studies investigating smoking intention among adolescent e-cigarette users have approached data analysis using a variable centered-approach e.g. logistic regression models to demonstrate associations between e-cigarette use and smoking intention (or its predictors such as attitudes toward smoking) (Bunnell et al., 2014; Wills et al., 2015b et al., 2014; Primack et al., 2015). In contrast, a person-centered approach classifies individuals into distinct groups based on shared characteristics or their response patterns to selected variables (Jung et al., 2008; Laursen and Hoff 2006). A person-centered analysis is more

advantageous for research designs that aim to examine cluster of traits within people and determine group differences in specific outcomes of interest (Laursen and Hoff, 2006).

Person-centered analyses have been previously utilized in studies conducted on the general adolescent population to deepen understanding of various patterns of tobacco use and associated trajectories including progression to other substance use (Dutra, Glantz, Lisah, and Song, 2017; Lisha, Thrul, and Ling, 2019; Morean et al., 2015; Morean, Kong, Camenga, Cavallo, Simon, and Krishnan-Sarin, 2016; Nassim, Blank, Cobb, and Eissenberg, 2012; Yu, Sacco, Choi, and Wintemberg, 2018). However, the use of person-centered analysis to investigate smoking intention specifically in the adolescent e-cigarette user subpopulation is limited. By using a person-centered approach to data analysis, adolescent e-cigarette users who share similar characteristics in relation to the predictors of smoking intention can be identified. This will be helpful in characterizing the adolescent e-cigarette subpopulation and identifying the subset that is most likely to exhibit smoking intention.

The Current Study

The majority of adolescent e-cigarette users do not have smoking intention (Bunnell et al., 2014; Wills et al., 2015b; Primack et al., 2015), an indication that adolescent e-cigarette users may have varied lived experiences and exposures that inform the development of smoking intention in some and not in others. For example, within the adolescent e-cigarette subpopulation, there could be differential exposures to smoking-related background factors (such as pro-tobacco ads), varying levels of risk-taking propensity, and differences in smoking-related perceptions and norms, which are all

factors that determine smoking intention. The current study aims to use a person-centered approach to data analyses to classify adolescent e-cigarette users who have never smoked conventional cigarettes into different subgroups based on theoretically-selected predictors of smoking intention and identify subgroups that are most likely to exhibit intention to smoke conventional cigarettes. The findings from this study will identify adolescent e-cigarette users at most risk of having intention to smoke conventional cigarettes and guide the development of targeted programs to prevent adolescents' progression from e-cigarette use to conventional cigarette smoking.

Research Questions and Hypotheses

a) ***Can adolescent e-cigarette users be classified into subgroups using their background media exposures, attitudes, subjective norms, and perceived behavioral control over conventional cigarette smoking?*** I hypothesize that there will be distinct subgroups of adolescent e-cigarette users based on variations in their background media exposures, attitudes, subjective norms, and perceived control over conventional cigarette smoking.

b) ***Which adolescent e-cigarette user subgroup is most likely to exhibit intention to smoke conventional cigarettes?*** I hypothesize that adolescent e-cigarette user subgroup with the least favorable scores on background media exposures, attitudes, subjective norms, and control factors over conventional cigarette smoking will be the most likely to have intention to smoke conventional cigarettes.

METHODS

Study participants

Cross-sectional data on 8th and 10th grade students were obtained from the Monitoring the Future Surveys of 2014-2017 (Johnston et al., 2017b). Students were included in the current study if they were current e-cigarette users who had never smoked conventional cigarettes. Current e-cigarette use was defined as past 30-day e-cigarette use and was measured via one item: “During the last 30 days, on how many days (if any) have you used electronic cigarettes (e-cigarettes)?” Response was on a 6-point scale ranging from “none” to “20-30 days”. Students reporting no e-cigarette use were excluded from the current study; students reporting any e-cigarette use were included. Conventional cigarette use was determined via two items: “Have you ever smoked cigarettes?” (students answering “yes” were omitted from the current study) and “If you have never smoked, do you think you will try smoking cigarettes sometime this year?” (students who responded “already tried” were excluded from the current study). The resulting total sample size for the current study was N = 1357 8th and 10th grade current e-cigarette users who had never smoked conventional cigarettes.

Measures

Intention to smoke conventional cigarettes

For the purpose of this study, smoking intention is defined as intention to smoke conventional cigarettes in the current year, measured using a single item: “If you have never smoked, do you think you will try smoking cigarettes sometime this year?” Response was on a 4-point scale: 1="I definitely will" 2="I probably will" 3="I probably will not" 4="I definitely will not." Consistent with previous studies, (Dube et al., 2013;

Gritz et al., 2003; Wills et al., 2015b; Soneji et al., 2017b) responses were dichotomized, with the response “I definitely will not” indicating firm intention not to smoke conventional cigarettes (no), and other responses (1="I definitely will" 2="I probably will" 3="I probably will not") suggesting intention to smoke conventional cigarettes in the current year (yes).

Background media exposures

Perceived influence of antismoking advertisements was measured via one item: “To what extent do you think such ads (anti-smoking commercials or "spots" that are intended to discourage cigarette smoking) on TV, radio, billboards or in magazines and newspapers have made you less favorable toward smoking cigarettes?” Responses were on a 5-point scale ranging from "not at all (1)" to "to a very great extent (5)."

Ownership of tobacco promotional items was measured using a single item that asks about ownership of tobacco promotional items: “Some companies make clothing, hats, bags, or other things with a tobacco brand on it. Do you have a piece of clothing or other thing that has a tobacco brand name or logo on it?” Response: 1="No" 2="Yes." (2).

Risk-taking propensity was measured by deriving the average of two items: “I get a real kick out of doing things that are a little dangerous” and “I like to test myself every now and then by doing something a little risky.” Response for each of the two items was on a 5-point scale ranging from “Disagree” (1) to “Agree” (5). Higher values on the averaged items indicates higher risk-taking propensity.

Attitudes toward conventional cigarette smoking

This was assessed using two separate variables: perceived addictiveness of conventional cigarette smoking and perceived harm of conventional cigarette smoking.

Perceived addictiveness of conventional cigarettes smoking was a composite variable derived from two items: “How much do you agree or disagree with the following statements?” “I could smoke a pack a day for a year or more and still be able to quit if I wanted to;” and “At my age, smoking is not too dangerous because you can always quit later.” Responses for each measure are on a 5-point scale: "disagree” (1), “mostly disagree” (2), “neither” (3), “mostly agree” (4), and “agree” (5). These items have been used in previous studies to assess addiction perceptions among adolescents (Arnett, 2000; Halpern-Felsher et al., 2004; Owotomo et al., 2018b). These two items were reverse coded and averaged to form a composite variable. Higher scores reflect higher perceived addictiveness.

Perceived harm of cigarette smoking was measured via one item: “How much do you think people risk harming themselves (physically or in other ways), if they smoke one or more packs of cigarettes per day?” Responses are on a 4-point scale ranging from “no risk” (1) to “great risk” (4).

Subjective norms toward conventional cigarette smoking

Subjective norms toward conventional cigarette smoking was measured as two separate constructs (injunctive and descriptive norms) as guided by TPB (Ajzen, 2012; Fishbein and Ajzen, 2010) with details highlighted below:

Friends’ disapproval of smoking (Injunctive norm) was measured using three items: “How do you think your close friends feel (or would feel) about you doing each of

the following things?" "Smoking one or more packs of cigarettes per day;" "smoking cigarettes occasionally;" and "smoking cigarettes every day." Response to each question range from 1="not disapprove" 2="disapprove" 3="strongly disapprove." All three items were retained for analysis to reflect norms toward different levels of conventional cigarette smoking. For example, friends' perception of smoking cigarettes occasionally may be different from their perceptions about smoking a pack or more of cigarettes per day.

Peer smoking (Descriptive norm) was measured via one item: "How many of your friends would you estimate smoke cigarettes?" Responses were on a 5-point scale ranging from "none" (1), "a few" (2), "some" (3), "most" (4), "all" (5).

Control beliefs/factors over conventional cigarette smoking

The current dataset does not contain direct measures for perceived behavioral control over conventional cigarette smoking. Thus, indirect measures of PBC (belief-based measures) were used as discussed above. Access to conventional cigarettes and parental monitoring (control beliefs/factors discussed above) were operationalized as facilitating and constraining factors, respectively in the current study.

Access to conventional cigarettes was measured via one item: "How difficult do you think it would be for you to get each of the following types of drugs, if you wanted some? "Cigarettes." Response was on a 5-point scale namely: "probably impossible" (1), "very difficult" (2), "fairly difficult" (3), "fairly easy" (4), "very easy" (5).

Parental monitoring was a composite variable derived by averaging responses from three items: (1) *"My parents know where I am after school" (2) "When I go out at*

night, my parents know whom I am with" (3) "When I go out at night, my parents know where I am."(Responses were "never" (1), rarely (2), sometimes (3), most of the time (4), "always" (5). These three items have been shown to load on a single latent factor and have been used to assess parental monitoring in previous studies (Dever et al., 2012). Higher values indicate higher parental monitoring.

Covariates

The study covariates include grade (8th or 10th), race/ethnicity, sex (male/female), urbanicity (rural or urban), country region (Northeast, Midwest, South, West), and parent education level.

Race/ethnicity was categorized into White non-Hispanic, Black non-Hispanic, and Hispanic (datasets on other racial groups were unavailable in the public use datafiles accessed for this study).

Parent education level was measured with a 6-point scale ranging from "completing grade school or less" to "graduate or professional school after college." The average of both parent education levels (single parent's education level was used for students with single parents) was determined and used as an indicator of socioeconomic status (SES).

Statistical analysis

Sample descriptive statistical analysis was conducted using SPSS version 25 (IBM, 2017). A latent class regression analysis was then conducted on Mplus version 8 (Muthén and Muthén, 2017) using the classical three-step analytic approach including a latent class analysis, model fit determination and class enumeration, and regression of the

identified latent classes on an observed dependent variable (Feingold et al., 2014). Unlike the one-step approach which enlists the dependent variable as one of the indicator variables for the latent class analysis, the classical three-step approach does not include the dependent variable as an indicator, thus preventing it from influencing class formation (which is in keeping with the analytic plan for this study) (Feingold et al., 2014). Accordingly, in the current study, smoking intention was not included as an indicator variable for determining the latent classes, instead it served as a dependent variable after the latent classes had been identified.

A latent class analysis was first conducted to identify underlying homogenous subgroups (classes) of adolescent e-cigarette users using their responses to eleven smoking-related indicator variables—perceived addictiveness of conventional cigarette smoking, perceived harm of conventional cigarette smoking, perceived influence of antismoking ads, peer smoking, friends' approval/disapproval of smoking ≥1 pack of cigarettes per day, friends approval/disapproval of smoking cigarettes occasionally, friends approval/disapproval of smoking cigarettes every day, ownership of tobacco promotional items, access to cigarettes, parental monitoring, and risk-taking propensity. The optimal number of classes was determined by running models iteratively, starting with one-class model followed by a point increment in number of classes (from one to six) while examining fit indices for each class compared to the previous one (Lisha, Thrul, and Ling, 2019; Morean et al., 2016; Muthén and Muthén, 2017; Porcu and Gambiano, 2017). Conditional probabilities (for categorical variables) and mean responses (for continuous variables) were used to assign participants to classes. The

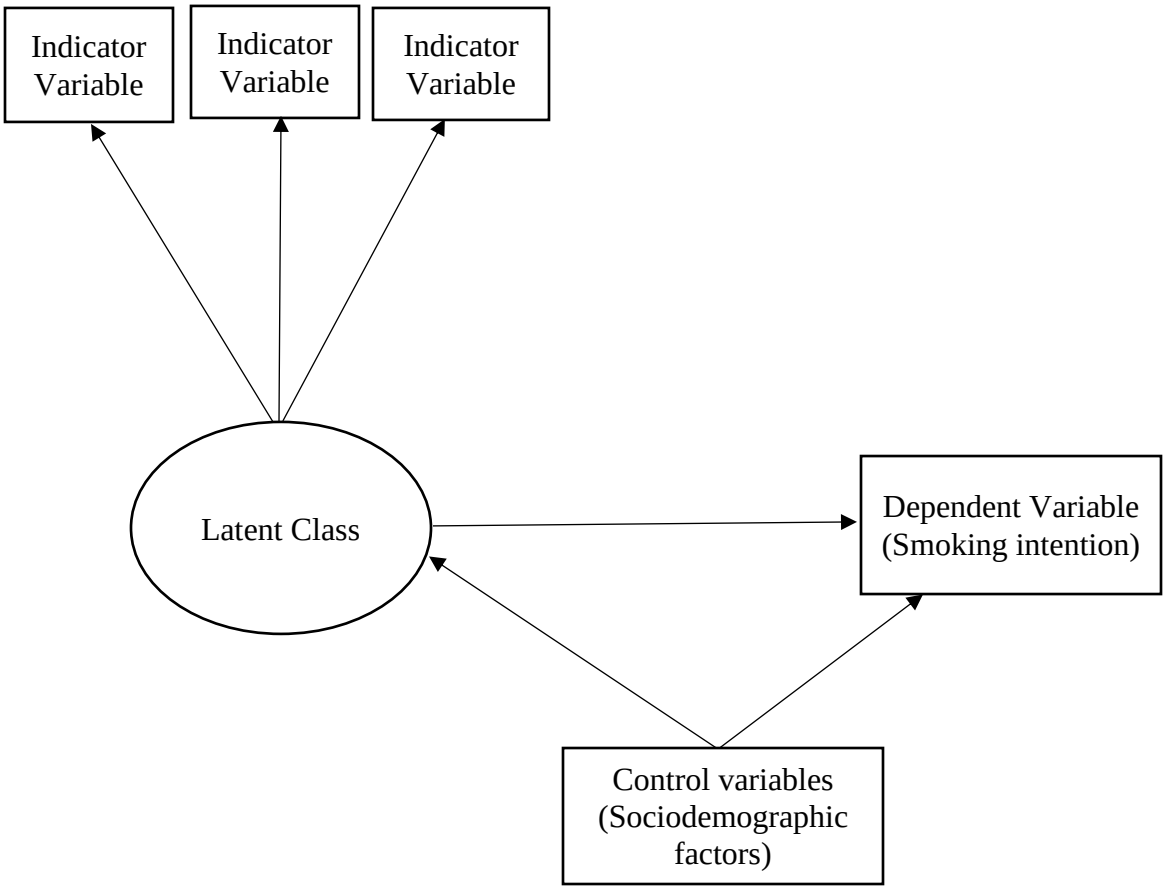
variances of the indicator variables were constrained to be equal across classes, which is the default measurement invariance recommended for latent class analysis (Muthén and Muthén, 2017). The class probabilities and variables used for estimation were saved for subsequent multivariable regression analyses.

The best fitting model was determined using a combination of factors (fit indices, parsimony, and interpretability—substantive meaning of the latent classes; Chung, Flaherty, Schafer, 2006; Jung et al., 2008; Porcu et al., 2017). The two major fit indices used for model fit determination were sample-size adjusted Bayesian Information Criterion (BIC) and Bootstrap Likelihood Raito Test (BLRT) (Nylund, Asparouhov, & Muthén, 2007). Also, a scree plot of BIC by number of classes was constructed to determine the inflection point (elbow) where the substantial decrease in BIC flattened out (Porcu et al., 2017). Entropy, which is a measure of the degree of separation between the created latent classes, (Feingold et al., 2014) was also considered in determining model fit, with values closer to 1 indicating better fit. In totality, the model with the fewest number of interpretable classes, smallest BIC value (as indicated by the BIC plot), and a statistically significant (p <.05) BLRT value was considered the best fit and reported. In addition, analysis of co-variance (ANCOVA) and Tukey's HSD (honestly significant difference) post-hoc test were conducted to determine statistically significant differences in specific indicator variables across the identified latent classes.

The saved class probabilities from the latent class analysis were imported to SPSS, covariates were merged to imported data file, and the latent class variable was dummy coded. The merged data was exported back to Mplus for multivariable regression

analysis. Multivariable logistic regression was thereafter conducted to determine the adolescent e-cigarette user subgroup that was most likely to have smoking intention. The regression model examined the association between the identified subgroups (latent classes) of adolescent e-cigarette users (independent variables) and smoking intention (dependent variable) while controlling for sociodemographic variables including grade, sex, race/ethnicity, urbanicity, country region, and parent educational level. Two regression models were conducted with the reference category (latent class) changed for each model, in order to compare each latent class to all others. For the entire analysis, study sample weights were applied to achieve national representativeness of sample (Johnston et al., 2017b), and missing data was handled using full information maximum likelihood (FIML)--which is based on using all available information to estimate the model by obtaining the maximum likelihood of the observed data's parameter estimates (Pigott, 2001). See Figure 3.1 for a graphical representation of the analytic framework for this study.

Figure 3.1: Study analytic framework



Note: Indicator variables: Ownership of tobacco promotional items, friends approval/disapproval of smoking (occasionally daily, ≥1 pack of cigarettes a day), peer smoking, cigarette harm perception, cigarette addiction perception, perceived influence by antismoking ads, access to cigarettes, parental monitoring, and risk-taking propensity. Control variables: Race/ethnicity, sex, grade, urbanicity, parent education level.

RESULTS

Descriptive Statistics

In the current sample of 1357 adolescent e-cigarette users who had never smoked conventional cigarettes, 41.3% had intention to smoke conventional cigarettes in the near future. Among those who had smoking intention, 53.4% were females, 65.1% identified

as White Non-Hispanic (28.3% Hispanic, and 6.6% Black Non-Hispanic), 43.2% were in 8th grade, and 83.6% lived in urban areas (not presented in table). The descriptive statistics of the entire sample are presented in Table 3.1.

Table 3.1: Demographic characteristics of sample, N = 1,357

		n (%)
Sex	Male	712 (52.5)
	Female	616 (45.4)
	Missing	28 (2.1)
Grade	Grade 8	561 (41.4)
	Grade 10	796 (58.6)
Race/ethnicity	Black	149 (11.0)
	Hispanic	376 (27.7)
	White	833 (61.4)
U.S Census region	North East	245 (18.0)
	North Central	307 (22.6)
	South	503 (37.1)
	West	302 (22.3)
Urbanicity	Rural	192 (14.1)
	Urban	1165 (85.9)
Maternal Education	Less than high school	62 (4.6)
	Some high school	94 (6.9)
	High school graduate	262 (19.3)
	Some college	200 (14.7)
	College graduate	367 (27.0)
	Graduate school	250 (18.4)
	Missing	122 (9.0)
Paternal Education	Less than high school	56 (4.1)
	Some high school	125 (9.2)
	High school graduate	313 (23.1)
	Some college	157 (11.6)
	College graduate	334 (24.6)
	Graduate school	196 (14.4)
	Missing	176 (13.0)

Latent Class Analysis

A three-class solution was determined to be the best fit for the data based on a combination of findings from the model fit indices, BIC scree plot, parsimony, and substantive meaning of the latent classes. See Table 3.2 for the BIC and BLRT values and *p*-values obtained for each model specification. Although the four-class model had the lowest BIC, the BIC scree plot (see Figure 3.2) shows that the substantial decline and flattening out of the BIC occurred in the three-class model. Also, upon interpretation of the latent classes, there was no clear distinction between the latent classes for the four-class model. However, the three-class solution generated distinct latent classes with substantive meanings. Thus, a three-class solution was deemed best fit and extracted. The plots depicting these classes are presented in Figure 3.3. The estimated conditional probabilities (presented as percentages) for the categorical variables and means (for continuous variables) for each latent class are reported in Table 3.3. In addition, the demographic and smoking-related characteristics of each class are presented in Table 3.4.

Table 3.2: Fit Statistics to Determine LCA Solution (N = 1357)*

	1 class	2 class	3 class	4 class	5 class	6 class
Log likelihood	-17565.30	-16672.17	-16031.86	-15801.78	-15611.20	-15443.71
Parameters	21	36	51	66	81	96
BIC	35282.07	33604.00	32431.59	32079.63	31806.66	31579.86
Sample-size adjusted BIC (aBIC)	35215.37	33489.64	32269.59	31869.97	31549.36	31274.91
Entropy		0.925	0.957	0.965	0.962	0.964
LMR p-value		0.000	0.0000	0.01	0.729	0.768
Distribution of profiles		36.2%, 63.8%	13.6%, 29.8%, 56.6%	13.4%, 7.0%, 55.6%, 24.0%	12.5% 5.9% 20.2% 51.2% 10.1%	5.7% 20.2% 8.7% 41.0% 51.2% 10.1%

* Default: variances constrained to be equal for all variables

Figure 3.2: BIC scree plot

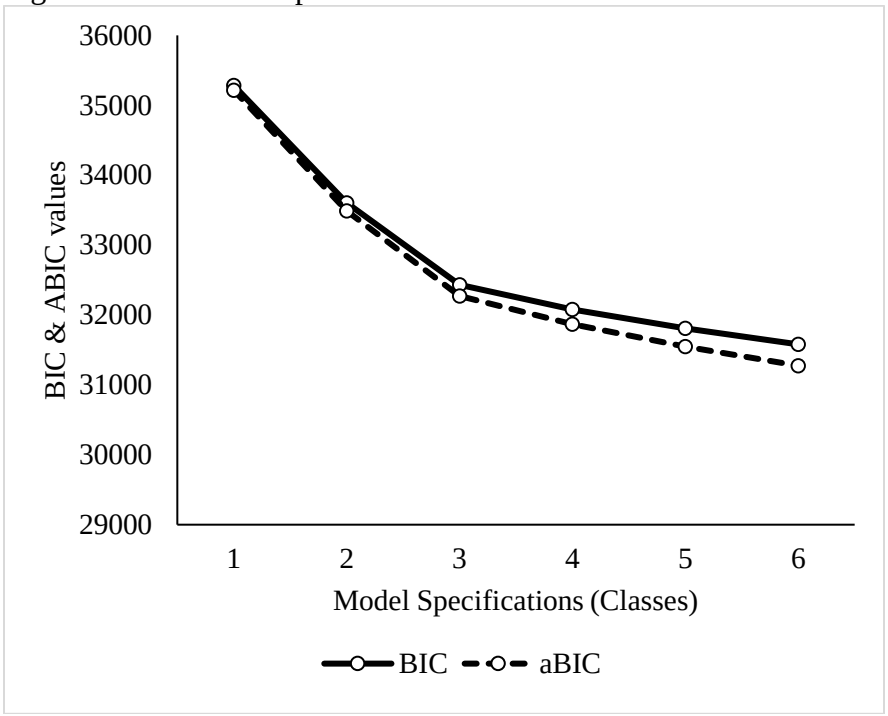
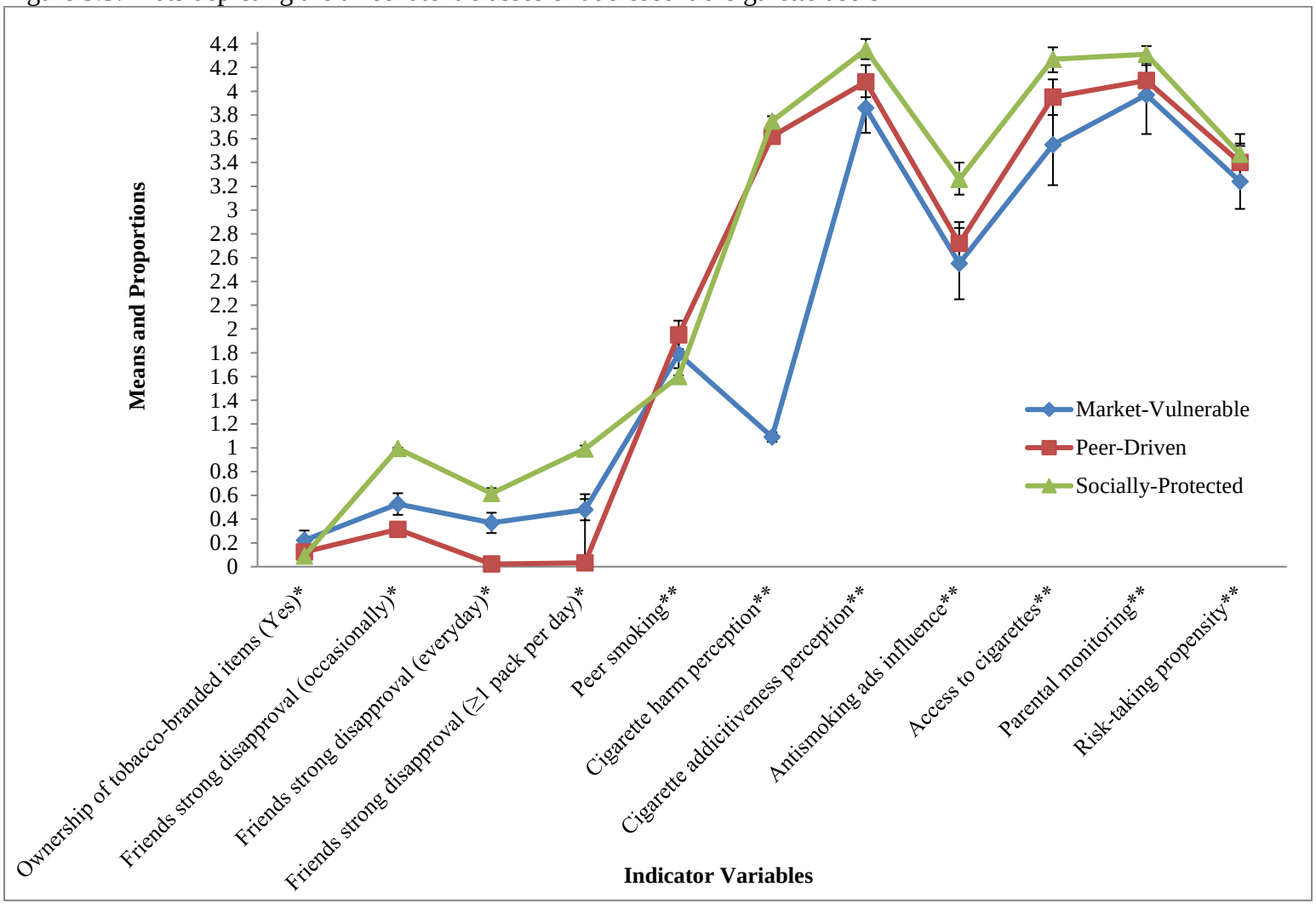


Figure 3.3: Plots depicting the three latent classes of adolescent e-cigarette users



*Values represent proportions (e.g. 22.2% = 0.22); **Values represent means of responses to items.

Table 3.3: Estimated conditional probabilities and means for each latent class of adolescent e-cigarette users

	Overall sample	*Market-Vulnerable Class*	*Peer-Driven Class*	*Socially-Protected Class*
Composition (n) (%)	1357 (100)	184 (13.6)	405 (29.8)	768 (56.6)
Indicator Variables				
Ownership of tobacco branded merchandise (% Yes)	11.8	22.2[a]	12.4[b]	9.0[b]
Friends feelings about smoking cigarettes occasionally				
Not disapprove (% Yes)	10.7	32.2[a]	21.3[a]	0.0[b]
Disapprove (% Yes)	16.4	15.1[a]	47.5[b]	0.5[c]
Strongly disapprove (% Yes)	72.8	52.7[a]	31.3[b]	99.5[c]
Friends feelings about smoking cigarettes everyday				
Not disapprove (% Yes)	18.2	33.8[a]	42.8[b]	1.5[c]
Disapprove (% Yes)	41.2	29.3a	55.0[b]	36.8[c]
Strongly disapprove (% Yes)	40.6	36.8[a]	2.2[b]	61.7[c]
Friends feelings about smoking ≥1 pack cigarettes per day				
Not disapprove (% Yes)	12.0	33.9[a]	25.0[b]	0[c]
Disapprove (% Yes)	24.4	18.2[a]	71.9[b]	0.1[c]
Strongly disapprove (% Yes)	63.5	47.9[a]	3.1[b]	99.9[c]
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*
Peer smoking	1.73 (0.87)	1.79 (0.87)[a]	1.95 (0.87)[a]	1.60 (0.87)[b]
Perception of harm of conventional cigarette smoking	3.36 (0.97)	1.09 (0.39)[a]	3.62 (0.39)[b]	3.75 (0.39)[c]
Perception of addictiveness of conventional cigarette smoking	4.21 (1.04)	3.86 (1.03)[a]	4.08 (1.03)[a]	4.35 (1.03)[b]
Perceived influence of antismoking ads	3.00 (1.55)	2.55 (1.52)[a]	2.72 (1.52)[a]	3.26 (1.52)[b]
Access to conventional cigarettes	4.09 (1.26)	3.55 (1.24)[a]	3.95 (1.24)[b]	4.27 (1.24)[c]
Parental monitoring	4.20 (0.89)	3.97 (0.88)[a]	4.09 (0.88)[a]	4.31 (0.88)[b]
Risk propensity	3.41 (1.14)	3.24 (1.14)[a]	3.40 (1.14)[a, b]	3.47 (1.14)[b]

Higher scores on the variables indicate higher peer smoking, higher perceived harm and addictiveness of conventional cigarette smoking, higher perceived influence of antismoking ads, higher perceived access to conventional cigarettes, higher parental monitoring, and higher risk-taking propensity.
ANOVA and Tukey's post-hoc test was used to test statistically significant differences in means and proportions of the indicator variables between latent classes. Matching superscripts indicate no statistically significant differences between latent classes (p<.05).

Table 3.4: Demographic and smoking-related characteristics of each latent class of adolescent e-cigarette users

		Overall sample	*Market-Vulnerable Class*	*Peer-Driven Class*	*Socially-Protected Class*
Composition (n) (%)		1357 (100)	184 (13.6)	405 (29.8)	768 (56.6)
Smoking Intention (% Yes)		41.3	34.4[a]	55.3[b]	35.5[a]
Race/ethnicity (%)	Black	11.0	18.3[a]	11.8[b]	8.7[b]
	Hispanic	27.7	40.9[a]	31.1[b]	22.7[c]
	White	61.4	40.8[a]	57.1[b]	68.6[c]
Sex (%)	Male	53.6	63.9[a]	54.9[b]	50.6[b]
	Female	46.4	36.1[a]	45.1[b]	49.4[b]
Grade (%)	8th grade	41.4	57.1[a]	41.0[b]	37.8[b]
	10th grade	58.6	42.9[a]	59.0[b]	62.2[b]
Urbanicity (%)	Rural	14.1	17.7[a]	16.5[a]	12.1[b]
	Urban	85.9	82.3[a]	83.5[a]	87.9[b]

Matching superscripts indicate no statistically significant differences between latent classes ($p<.05$).

Class Interpretation

Socially-protected class

This class comprises 56.6% of adolescent e-cigarette users in the current sample. The class had the lowest score on peer smoking and the highest proportion of friends who strongly disapproved of conventional cigarette smoking in any level (e.g. 99.1% of their friends disapproved of smoking ≥1 pack of cigarettes daily). They also reported highest scores on parental monitoring. It also had the highest perception of the harm and addictiveness of conventional cigarette smoking and reported the highest perceived influence by antismoking ads. However, they had the highest access to cigarettes, and their score on risk-taking propensity was higher than market-vulnerable class, though similar to the peer-driven class. See Table 3.3 for more details on the estimated conditional probabilities and means of this class.

Peer-driven class

Comprising 29.8% of adolescent e-cigarette users, this class had the highest score on peer smoking and the lowest proportion of friends who strongly disapproved of daily cigarette smoking. In fact, only 3.1% of their friends strongly disapproved of smoking ≥1 pack of cigarettes daily. Also, compared to the socially-protected class, this class had a lower score on parental monitoring, lower perceptions of the addictiveness of conventional cigarette smoking, and lower perceived influence by antismoking ads. However, their perceptions of the harm of conventional cigarette smoking was higher than the market-vulnerable class but lower than the socially-protected class. This class also had a relatively higher access to cigarettes than the market-vulnerable class (but

lower than the socially-protected class). Their score on risk-taking propensity was not different from the other two classes. See Table 3.3 for more details on the estimated conditional probabilities and means of this class.

Market-vulnerable class

It comprises 13.6% of adolescent e-cigarette users. This class of adolescent e-cigarette users ranked highest in ownership of tobacco promotional items (22.2%). They had the lowest perceptions of the harm of conventional cigarette smoking, and their perceptions of the addictiveness of cigarette smoking was lower than the socially-protected class but same as than the peer-driven class. Also, compared with the socially-protected class, they had lower perceived influence by antismoking ads and lower score on parental monitoring and risk-taking propensity. Their score on peer smoking was same as the peer-driven class but higher than the socially-protected class. However, compared with the peer-driven class, they reported a higher proportions of friends who strongly disapproved of both daily smoking and smoking ≥1 pack of cigarettes per day (36.8% and 47.9%, respectively). The class also reported the least access to conventional cigarettes. See Table 3.3 for more details on the estimated conditional probabilities and means of this class.

Class demographic and smoking-related characteristics

The peer-driven class had the highest percentage of adolescent e-cigarette users (55.3%) with smoking intention. However, the prevalence of smoking intention was similar for the market-vulnerable class and socially-protected class (34.4% vs 35.5%).

The market-vulnerable class comprised the majority of racial minorities (Black non-Hispanic—18.3%, Hispanic—40.9%), males (63.9%), and 8th grade students (57.1%). See Table 3.4 for more details on the characteristics of this class.

Multivariable Logistic Regression

Two separate regression models were conducted to ensure each of the three latent classes was compared with the others. In the first adjusted regression model (with socially-protected class as the referent class), the peer-driven class was found to be more likely than the socially-protected class to have smoking intention (Adjusted odds ratio, [AOR] = 2.46; 95% CI, 1.84 - 3.28, see Table 3.5). There was no statistically significant difference between the socially-protected class and the market-vulnerable class regarding smoking intention. In the second adjusted regression model (with market-vulnerable class as the referent class), the peer driven class had 2.29 times (AOR= 2.29; 95% CI, 1.48 - 3.53, see Table 3.5) the odds of having smoking intention compared with the market-vulnerable class.

Table 3.5: Adjusted multivariable logistic regression showing association between latent classes and smoking intention (*N* = 1357)

				Smoking Intention		
	B (SE)	AOR	95% CI	B (SE)	AOR	95% CI
Latent Classes						
(Reference: Socially-Protected)						
Market-Vulnerable	0.07 (0.21)	1.07	0.71 – 1.62	--	--	--
Peer Driven	0.90 (0.15)	2.46***	1.84 – 3.28	--	--	--
(Reference: Market-Vulnerable)						
Peer-Driven	--	--	--	0.90 (0.15)	2.29***	1.48 – 3.53
Socially-Protected	--	--	--	-0.07 (0.21)	0.93	0.62 – 1.41
Sex (Reference: Female)						
Male	-0.53 (0.14)	0.59***	0.45 – 0.77	-0.53 (0.14)	0.59***	0.45 – 0.77
Grade (Reference: 10th)						
8th	0.16 (0.14)	1.18	0.89 – 1.55	0.16 (0.14)	1.18	0.89 – 1.55
Race/ethnicity (Reference: White)						
Black	-0.93 (0.23)	0.40***	0.45 – 0.77	-0.93 (0.23)	0.40***	0.45 – 0.77
Hispanic	0.03 (0.19)	1.03	0.71 – 1.49	0.03 (0.19)	1.03	0.71 – 1.49
Urbanicity (Reference: Urban)						
Rural	0.30 (0.18)	1.35	0.95 – 1.93	0.30 (0.18)	1.35	0.95 – 1.93
Country Region (Reference: West)						
Northeast	0.08 (0.24)	1.08	0.68 – 1.72	0.08 (0.24)	1.08	0.68 – 1.72
Northcentral	0.25 (0.22)	1.29	0.84 – 1.98	0.25 (0.22)	1.29	0.84 – 1.98
South	0.18 (0.19)	1.13	0.78 – 0.64	0.18 (0.19)	1.13	0.78 – 0.64
Parent Education	0.09 (0.06)	1.09	0.94 – 1.07	0.09 (0.06)	1.09	0.94 – 1.07

****p<.001; AOR: Adjusted Odds Ratio; CI: Confidence Interval. SE: Standard Error.*

DISCUSSION

Consistent with previous studies (Bunnell et al., 2014), 41% of adolescent e-cigarette users, in the current national sample, had intention to smoke conventional cigarettes in the near future. Although previous studies have established the direct association between adolescent e-cigarette use and smoking intention (Bunnell et al., 2014; Wills et al., 2015b; Primack et al., 2015), this study elevates the discourse by using a theory-driven person-centered approach to identify classes of adolescent e-cigarette users with varying tendencies to exhibit smoking intention. Indeed, I found three distinct classes of adolescent e-cigarette users (market-vulnerable, peer-driven, and socially-protected) with major differences in their background exposures to tobacco and anti-tobacco messages, risk-taking propensity, attitudes and norms toward conventional cigarette smoking, access to cigarettes, and parental monitoring. Notably, the peer-driven class of adolescent e-cigarette users was by far the most likely to have smoking intention and was characterized by negative attitudes and norms toward conventional cigarette smoking, higher access to cigarettes, and lower scores on parental monitoring. The other classes had relatively lower risk of having smoking intention possibly because of their balanced combination of risk and protective factors. For example, although the socially-protected class had highest access to cigarettes as well as high scores on risk-taking propensity, their positive attitudes and norms toward smoking and high scores on parental monitoring could have been protective. Similarly, the market-vulnerable class ranked highest in ownership of tobacco promotional items, had negative attitudes toward conventional cigarette smoking, and low scores on parental monitoring, however, their

low access to cigarettes, low scores on risk-taking propensity, and relatively higher proportion of friends who strongly discouraged daily cigarette smoking seemed to function as protective factors. These findings reveal the existence of subgroups of adolescent e-cigarette users with varying characteristics and potential risks of progressing to conventional cigarette smoking. The study also highlights the combination of risk and protective factors that may underlie the progression from e-cigarette use to conventional cigarette smoking among US adolescents.

Peer-driven adolescent e-cigarette users had the highest likelihood of exhibiting smoking intention. About one-third (29.6%) of adolescent e-cigarette users belonged in this class, with the majority of members (55.5%) having intention to smoke conventional cigarettes in the near future. In fact, peer-driven adolescent e-cigarette users were about 2.5 times more likely than the other two classes to have smoking intention. This may be due to the presence of risk factors and lack of protective factors that determine adolescent smoking behavior. Peer-driven adolescent e-cigarette users had negative attitudes and norms toward smoking, easy access to conventional cigarettes, and low scores on parental monitoring. Although they were quite aware of the harm associated with conventional cigarette smoking, their perception of its addictiveness was limited. Low perception of the addictiveness of conventional cigarette smoking has been linked to smoking intention among adolescent e-cigarette users in previous variable-centered studies (Arnett 2000; Halpern-Felsher et al., 2004). Findings from the current person-centered study, indicate that adolescent e-cigarette user subgroup at most risk of exhibiting smoking intention has low perceptions of the addictiveness of conventional cigarettes, negative descriptive and

injunctive norms toward smoking, low parental monitoring, and easy access to conventional cigarettes.

Adolescent e-cigarette users who had negative descriptive and injunctive norms toward conventional cigarette smoking were at risk of exhibiting smoking intention. Although both the peer-driven and market-vulnerable classes had a similar proportion of friends who smoked conventional cigarettes, the latter had a higher proportion of friends who strongly disapproved of daily cigarette smoking (2.2% vs 36.8%) and smoking ≥ 1 pack of cigarettes per day (3.1% vs 47.9%). Indeed, the peer-driven class was 2.3 times more likely to have smoking intention than the market-vulnerable class. This shows that friends' disapproval (positive injunctive norm) is a strong protective factor against conventional cigarette smoking among adolescent e-cigarette users. Prior variable-centered studies have reported that descriptive norm (having a high proportion of friends who smoke cigarettes) is associated with progression from e-cigarette use to smoking initiation (Barrington-Trimis et al., 2016a; Primack et al., 2015), however no association was found between injunctive norm (friends disapproval of smoking) and smoking initiation among adolescent e-cigarette users (Barrington-Trimis et al., 2016a). The current study findings extend the literature by demonstrating that both descriptive and injunctive norms can potentially influence smoking initiation among adolescent e-cigarette users, and adolescent e-cigarette users can be classified into subgroups based on their descriptive and injunctive norms toward conventional cigarette smoking. Indeed, adolescent e-cigarette users subgroup who had negative attitudes and social norms toward

smoking and were exposed to other risk factors such as easy access to cigarettes and low parental monitoring had the highest likelihood of exhibiting smoking intention.

Similarly, adolescent e-cigarette users who reported high parental monitoring were somewhat protected from other risk factors against smoking. The socially-protected class) who despite displaying characteristics that could make them at risk of initiating smoking (high risk-taking propensity and high access to cigarettes), were protected from exhibiting smoking intention by high parental monitoring coupled with positive attitudes and norms toward smoking. Conversely, the peer-driven class who lacked such protective factors, had the highest likelihood of exhibiting intention to smoke cigarettes. These findings suggest that adolescent e-cigarette users at most risk of progressing to conventional cigarette smoking have lots of risk factors in favor of smoking and lack protective factors against smoking such as parental monitoring. Based on the control beliefs of TPB, parental monitoring can act as a constraining factor that hinders the performance of smoking (Carvajal et al., 2004; Bohnert et al., 2009). When parental monitoring was high (as seen in the socially-protected class) the likelihood of having smoking intention was low. Conversely, when parental monitoring was low (as seen in peer-driven class) the likelihood of having smoking intention was high. Thus, parental monitoring may be an influential control factor in the smoking behavior of adolescent e-cigarette users who report other risk factors for smoking such as negative attitudes and norms toward smoking and high access to cigarettes. The role of parental monitoring in hindering the performance of risk behaviors among adolescents has been previously reported (Lippold, Greenberg, Graham, and Feinberg, 2014).

Adolescent e-cigarette users who reported high access to cigarettes also tended to report other risk factors for smoking, and that cluster was associated with smoking intention. Again, peer-driven e-cigarette users who had moderate access to cigarettes scored high on other risk factors for smoking. As a result, this subgroup had the highest proportion of e-cigarette users with smoking intention. Compared to the peer-driven class, the socially-protected and market-vulnerable classes had some protective factors against smoking (e.g. high parental monitoring and low access to cigarettes, respectively). Thus, it is plausible that easy access to cigarettes may influence smoking intention only among adolescent e-cigarette users who have other risk factors for smoking, as seen in the peer-driven class. Conversely, as demonstrated by the socially-protected and market-vulnerable classes, the influence of easy access to cigarettes on smoking intention may be balanced out by the existence of protective factors such as high perception of the harm and addictiveness of conventional cigarette smoking, friends' strong disapproval of smoking, and high parental monitoring. These findings suggest that access to cigarettes may predict smoking intention only among adolescent e-cigarette users who are concurrently exposed to other risk factors for smoking.

Sensation-seeking may be driving e-cigarette use among the socially-protected class. Adolescent e-cigarette users in this class had positive attitudes and norms toward conventional cigarette smoking and scored high on parental monitoring. Also, this class (together with the market-vulnerable class) had the lowest proportion of adolescent e-cigarette users who had smoking intention (35.5%). However, they reported high risk-taking propensity score similar to the peer-driven class but higher than the market-

vulnerable class. The fact that majority of adolescent e-cigarette users (56.6%) were in this class speaks clearly to the risk exploratory developmental stage of the study sample (Maslowsky, Owotomo, Huntley, and Keating, 2019). Curiosity and desire to experiment are the main reasons cited by adolescents for e-cigarette use (Kong et al., 2015; Patrick et al., 2016). Indeed, most adolescents using e-cigarettes may be driven by their desire to take calculated risks particularly given the portrayal of e-cigarettes as a safer alternative to conventional cigarettes. Moreover, the socially-protected class may be taking calculated risks considering that they are aware of the dangers associated with conventional cigarette smoking and may be using e-cigarettes as safer alternatives. Although adolescent e-cigarette users in this class may have low likelihood of having smoking intention relative to other adolescent e-cigarette subgroup, however, their risk of having smoking intention may be higher than that of the average adolescent never-user of tobacco products. For example, in a recent national study, Owotomo and Maslowsky, (2018a) found the prevalence of smoking intention to be 17% among adolescent never-smokers of conventional cigarettes. This is lower than the 35.5% and 34.4% reported among socially-protected and market-vulnerable e-cigarette users, respectively, in the current study, suggesting that these subgroups may remain at higher risk of having smoking intention compared with the average adolescent never-user tobacco user population.

Further, the market-vulnerable class remains at risk of smoking conventional cigarettes. Compared to the peer-driven class, the market-vulnerable class is less likely to have smoking intention, possibly because they are protected by positive social norms

toward smoking—as reflected by the higher proportions of friends who strongly disapproved of conventional cigarette smoking—and their low access to conventional cigarettes. Although only 13.6% of adolescent e-cigarette users were in the market-vulnerable class, the class had the highest percentage (22%) of adolescent e-cigarette users who owned tobacco promotional items, a known risk factor for conventional cigarette smoking among adolescents (Gilpin, Pierce, and Rosbrook, 1997). The class also had the highest proportions of racial/ethnic minorities, males, and 8th graders, which is not surprising given the tobacco industry strategy of targeting young and racial/ethnic minorities with tobacco promotional items (Feighery, Schleicher, Cruz, and Unger, 2008; Henriksen, Schleicher, Dauphinee, and Fortmann, 2012). The market vulnerable class remains at risk of smoking conventional cigarettes because they had the lowest perception of the harm and addictiveness of conventional cigarette smoking and (together with the peer-driven class) were the least influenced by antismoking ads. While the socially-protected class may be taking calculated risks regarding e-cigarette use, the market-vulnerable class may be risking e-cigarette use without being fully aware of the dangers associated with conventional cigarette smoking—a potential consequence of e-cigarette use. Although the market-vulnerable class is at risk of initiating smoking, they may not have developed smoking intention because they are protected by positive injunctive norms toward smoking and have limited access to conventional cigarettes.

Summary

Guided by the constructs of TPB, adolescent e-cigarette users can be classified into at least three subgroups depending on their exposures to a combination of risk and

protective factors that predict smoking intention. Indeed, all the TPB constructs were useful in characterizing adolescent e-cigarette users into subgroups and determining the subgroup at most risk of exhibiting smoking intention. Adolescent e-cigarette user subgroup (peer-driven class) with the highest likelihood of having smoking intention had low perception of the addictiveness of conventional cigarette smoking, lots of friends who smoked and very few friends who disapproved of conventional cigarette smoking. They also had high access to cigarettes and low scores on parental monitoring. About one-third of adolescent e-cigarette users had these characteristics which leave them at risk of having the intention to smoke. However, the majority of adolescent e-cigarette users were less likely to have smoking intention. This subgroup (socially-protected class) was well-informed about the harm and addictiveness of conventionally cigarette smoking, and were socially protected from conventional cigarette smoking—they had very few friends who smoked, lots of friends who strongly disapproved of conventional cigarette smoking, and parents who monitored them closely. In addition, e-cigarette use in the socially-protected class appeared to be driven by sensation-seeking. The final subgroup of adolescent e-cigarette users (market-vulnerable class) was also at low risk of having smoking intention possibly because they had limited access to cigarettes and were protected by friends who strongly disapproved of conventional cigarette smoking. However, the market-vulnerable class remains at risk of having smoking intention because they were highly exposed to tobacco marketing, had poor perceptions of the harm and addictiveness of conventional cigarette smoking, and were yet to be influenced by antismoking ads. Although a lesser proportion of adolescent e-cigarette users were in

the market-vulnerable class, it comprised the majority of racial/ethnic minorities (African-Americans and Hispanics), males, and the youngest (8th graders).

In sum, study findings suggest that the subgroup of adolescent e-cigarette users with the highest likelihood of exhibiting smoking intention has negative attitudes and norms toward conventional cigarette smoking, easy access to cigarettes, and are not closely monitored by their parents. Racial/ethnic minorities and the youngest adolescent e-cigarette users are particularly vulnerable due to their exposure to tobacco marketing and low perception of the harm and addictiveness of conventional cigarette smoking. Regardless of class membership, all adolescent e-cigarette users are at risk of nicotine addiction which potentially leaves them at risk of initiating conventional cigarette smoking.

Study Limitations

The study had some limitations. Its cross-sectional nature limits the interpretation of findings and causality cannot be inferred. However, the large national sample allows for the generalization of the study findings to the US 8th and 10th grade never-smoker e-cigarette user subpopulation who identify as White non-Hispanic, Black non-Hispanic, and Hispanic. Also, the person-centered approach to analysis provides novel and contextual information on the constellation of risk and protective factors contributing to smoking intention among adolescent e-cigarette users who have never smoked conventional cigarettes. Future longitudinal studies should examine the smoking trajectories of each of the adolescent e-cigarette user subgroup identified in the current study. This study was also limited by lack of a specific measure of perceived behavioral

control which limits the full demonstration of the constructs of TPB. However, the use of control factors (access to cigarettes and parental monitoring) as proxy measures still provided very useful information needed to characterize the adolescent e-cigarette user subpopulation based on their risks of exhibiting smoking intention. Finally, the measure of ownership of tobacco promotional items is outdated because it does not specify which tobacco product is branded on the item owned by survey participants. However, the measure has been used in previous studies to assess ownership of tobacco (conventional cigarettes) promotional items (Gilpin et al., 1997; Gilpin, Distefan, and Pierce, 2004). Future national surveys should use more specific measures of ownership of tobacco branded items to capture the promotional items of various tobacco products present in the current tobacco landscape. For example, promotional items for e-cigarettes are currently in circulation (Pokhrel, Fagan, Kehl, and Herzog, 2015). Regardless of the promotional item represented by the measure used for this study, a segment of the adolescent e-cigarette user population is at high risk of owning tobacco promotional items leaving them potentially vulnerable to using tobacco products.

Study Implications

This study provides an in-depth exploration of the underlying factors associated with smoking intention among adolescent e-cigarette users. It generates contextual understanding of the combination of risk and protective factors that drive smoking intention among adolescent e-cigarette users. In an age when adolescent e-cigarette use is considered an epidemic, findings from this study can guide future research and intervention geared toward addressing the progression from e-cigarette use to

conventional cigarette smoking among US adolescents. The study, the first of its kind, is a logical first step in unraveling the potentially complex mechanisms involved in the progression from e-cigarette use to conventional cigarette smoking. The study findings indicate that more research, particularly person-centered longitudinal studies, is needed to fully elucidate the underlying factors and processes involved in the initiation of conventional cigarette smoking among adolescent e-cigarette users. Nonetheless, the study findings suggest that tobacco control interventions such as age-restriction on sales and educational campaigns that were instrumental in reducing the prevalence of conventional cigarette smoking in the overall adolescent population may also be effective in curbing smoking initiation among adolescent e-cigarette users. However, such interventions, particularly those designed to address negative attitudes and norms toward conventional cigarette smoking, would have to be tailored specifically to the adolescent e-cigarette user population. Because the majority of adolescents may be using e-cigarettes for sensation-seeking, as suggested by this study, current educational campaigns should also emphasize the risk of nicotine addiction associated with e-cigarette use. Also, existing policies designed to protect racial/ethnic minorities from targeted tobacco marketing should be revisited as this segment of the population remains soft targets of the tobacco industry. Close parental monitoring of adolescent e-cigarette users may also be protective against smoking initiation and should be encouraged. Finally, age-restriction policies, particularly those increasing minimum age limits to 21, should be enacted and enforced both locally and nationally.

Chapter 4: Does e-cigarette use moderate the association between smoking intention and smoking initiation among adolescent never-smokers of conventional cigarettes? If so, how?

INTRODUCTION

Over the past few decades, comprehensive tobacco control interventions have led to significant declines in the prevalence of adolescent conventional cigarette smoking (USDHHS, 2014). During 2011-2018, prevalence of cigarette smoking declined from 15.8% to 8.1% among high school students and from 4.3% to 1.8% among middle school students (Gentzke et al., 2019). However, disparities in adolescent cigarette smoking remain with rates as high as 14.4% among high school students in West Virginia (compared with 3.8% in Utah) (CDC, 2018a) and 10.3% among American-Indian/Alaskan Native adolescents (compared with 2% among Asian adolescents) (Odani et al., 2018). A major consequence of cigarette smoking among adolescents is nicotine addiction which is characterized by smoking at a higher frequency and more difficulty with quitting smoking as adults (USDHHS, 2012). In fact, about 90% of adult smokers initiate smoking during adolescence, suggesting that smoking-related morbidity and mortality can be prevented by ensuring that adolescents remain smoke-free (USDHHS, 2014). Although adolescent cigarette smoking rates have declined over the past decades, e-cigarette use is an emerging public health threat that can potentially stall or reverse this decline (USDHHS, 2016).

E-cigarette use is a major risk factor for conventional cigarette smoking among adolescents. Adolescents who use e-cigarettes are at heightened risk of progressing to

conventional cigarette smoking (Barrington-Trimis et al., 2016a; Berry et al., 2019; Bold et al., 2018; Leventhal et al., 2015; Miech et al., 2017a; Soneji et al., 2017a; Unger et al., 2016). In fact, substantial evidence supports a causal effect of e-cigarette use on the transition from never to ever cigarette smoking (National Academies of Sciences, Engineering, and Medicine, 2018). Although the prospective association between e-cigarette use and conventional cigarette smoking has been widely reported, how e-cigarette use facilitates smoking initiation remains unclear. Several hypotheses have been raised to explain how e-cigarette use may predispose adolescents to conventional cigarette smoking including the potential addictiveness of nicotine-containing e-cigarettes; similar access points—commercial and social sources—for both e-cigarettes and conventional cigarettes; and the characteristic habitual and ritualistic smoking techniques that mimic and possibly prime e-cigarette users for conventional cigarette smoking (Schneider and Diehl, 2016). However, currently available empirical evidence suggests two major potential explanations—an addiction pathway and a smoking intention pathway (Goldenson et al., 2017; Primack et al., 2015). E-cigarette use may lead to nicotine addiction which potentially fuels future cigarette smoking (Goldenson et al., 2017). Similarly, e-cigarette use may lead to smoking intention—defined as lack of a firm commitment not to smoke cigarettes (Choi, Gilpin, Farkas, and Pierce, 2001; Wakefield, 2004)—a major antecedent to smoking initiation (Barrington-Trimis et al., 2016b; Wills et al., 2015b; Primack et al., 2015). The next few paragraphs summarize findings of studies supporting each of these pathways and end by proposing an additional intention-behavior moderation pathway.

Addiction Pathway

Nicotine addiction may play a role in the transition from e-cigarette use to conventional cigarette smoking. E-cigarettes can potentially deliver high concentrations of nicotine to the blood (Vansickel et al., 2012; Vansickel et al., 2013). For example, a single 5% pod for JUUL device (a type of e-cigarette—shaped in form of USB flash drive—which has gained popularity among adolescents in past few years) delivers an equivalent amount of nicotine to the blood as a pack of conventional cigarettes (Gentzke et al., 2019; Jackler et al., 2019). As a result, adolescents who vape nicotine-containing e-cigarettes are at high risk of nicotine addiction. A recent prospective cohort study on 10th grade students in Los Angeles, California, showed a positive association between nicotine concentration of e-cigarette vaped at baseline and progression to more frequent and intense e-cigarette use and conventional cigarette smoking at follow-up (Goldenson et al., 2017). E-cigarette users who vaped e-cigarettes with high nicotine concentrations (compared with those who vaped e-cigarettes with no nicotine) were seven times more likely to report higher number of cigarettes smoked per day at follow-up. Thus, e-cigarette use may lead to nicotine addiction, which potentially fuels continued e-cigarette use and/or progression to conventional cigarette smoking among adolescents (Goldenson, 2017).

Smoking Intention Pathway

Current evidence suggests that e-cigarette use may lead to the development of smoking intention among adolescents who have never smoked conventional cigarettes (Barrington-Trimis et al., 2016b; Bunnell et al., 2014; Wills et al., 2015b; Primack et al.,

2015). For example, Primack et al (2015) reported that adolescent e-cigarette users (compared with non-e-cigarette users) who had no smoking intention at baseline were about eight times more likely to progress to have smoking intention after one year of follow-up. Wills et al (2016a), in a study conducted among high school students in Hawaii, found a direct association between e-cigarette use and willingness to smoke. The study also found that smoking expectancies mediated the association between e-cigarette use and willingness to smoke—adolescents who used e-cigarettes were more likely to have positive smoking expectancies (e.g. perception that smoking will enhance social confidence and provide relaxation) which in turn predicted willingness to smoke. According to the Theory of Planned Behavior (TPB), intention precedes behavior (Ajzen 1991; Ajzen et al., 2007; Ajzen 2012), and smoking intention is a major antecedent to and predictor of conventional cigarette smoking (deVries et al., 1995; Pierce et al., 1996). In the Wills et al (2016a) study, willingness to smoke was indeed found to prospectively predict smoking onset. Thus, adolescent e-cigarette use may lead to the development of smoking intention, which is an established predictor of smoking initiation (deVries et al., 1995; Pierce et al., 1996).

Intention-Behavior Moderation Pathway

Although the prospective association between adolescent e-cigarette use and smoking intention has been established, how e-cigarette use influences the initiation of conventional cigarette smoking beyond the development of smoking intention is yet to be fully elucidated. Smoking intention and e-cigarette use are strong independent predictors of conventional cigarette smoking among adolescents (Primack et al., 2015; Berry et al.,

2019). Thus, it is possible that e-cigarette use and smoking intention may interact to influence smoking initiation among adolescent never-smokers. For example, progression from smoking intention to smoking initiation may be dependent on e-cigarette use status. Likewise, progression from e-cigarette use to smoking initiation may be dependent on smoking intention status.

Prior studies have focused on demonstrating how the association between e-cigarette use and smoking initiation differs based on background smoking intention status. For example, Barrington-Trimis et al (2016a) found that among Southern California adolescents who had no smoking intention at baseline, e-cigarette users were about 10 times more likely than never e-cigarette users to have initiated cigarette smoking at one-year follow-up. In other studies that classified adolescents using their baseline risks for smoking initiation, e-cigarette use was also found to be a strong predictor of smoking initiation among low-risk adolescents (Berry et al., 2019; Wills et al., 2016b). While results of the strong association between e-cigarette use and smoking initiation have been consistent across studies for adolescents who do not have smoking intention (or classified low-risk for smoking initiation), results among adolescents who have smoking intention (or classified high risk for smoking initiation) have been mixed. In the Barrington-Trimis et al (2016a) study, among adolescents who had intention to smoke at baseline, the likelihood of initiating smoking at follow up was not different for e-cigarette users and never-users. However, Berry et al (2019) reported that the odds of initiating smoking was 3.5 times higher for e-cigarette users than never-users among adolescents who were classified high-risk for smoking initiation. Among Hawaiian

adolescents classified high-risk for smoking initiation, the association between e-cigarette use and smoking initiation varied depending on how risk classification was determined (Wills et al., 2016b). When risk classification was determined by smoking propensity/willingness to smoke, e-cigarette use was not predictive of smoking initiation among adolescents who indicated willingness to smoke at baseline, however, when rebelliousness and parental support were used to classify risk status, e-cigarette use was found to predict smoking initiation among adolescents with high rebelliousness and low parental support. Thus, while existing studies indicate that e-cigarette use predicts smoking initiation among adolescents who have no intention to smoke, whether or not e-cigarette use predicts smoking initiation among adolescents who have smoking intention remains unclear.

It is important to ascertain the nature of the interaction that potentially exists between e-cigarette use and smoking intention because mixed findings from existing studies can lead to divergent conclusions with varying research and practical implications. For example, if adolescent e-cigarette users progress to smoking initiation even without having smoking intention at baseline (as indicated by Barrington-Trimis et al 2016a), then it can be inferred that smoking intention is not a predictor of smoking initiation among adolescent e-cigarette users. On the other hand, if e-cigarette use predicts smoking initiation among adolescent who have smoking intention (or who are at high risk of initiating smoking) (as indicated by Berry et al 2019 and Wills et al 2016b), then e-cigarette use may be considered a factor that increases the risk of smoking initiation among adolescents who already have intention to smoke. This latter

interpretation is consistent with the intention-behavior relation of TPB which posits that intention is more likely to lead to behavior in the presence of factors that facilitate the performance of the behavior (Ajzen, 1991; Sheeran, 2002). Considering the established strong influence of e-cigarette use on adolescent smoking initiation (Soneji et al., 2017a), one would expect the association between smoking intention and smoking initiation to be stronger among adolescent e-cigarette users than never e-cigarette users. However, such assertions cannot be made from currently available evidence, thus, more studies are needed to ascertain whether and how e-cigarette use moderates the association between smoking intention and smoking initiation (intention-behavior relation) among adolescent never smokers of conventional cigarettes.

Further, as explained by the TPB, the intention-behavior relation may also be moderated by other factors besides e-cigarette use. Perceived behavioral control (PBC) is the perception of how easy or difficult it is to perform a target behavior (Ajzen, 1991, Ajzen et al., 2007). It is directly associated with smoking intention and also moderates the association between smoking intention and smoking initiation (Carvajal et al., 2004; Van De Ven, Engels, Otten, and Van Den Eijnden, 2006; Van den Eijnden, Spijkerman, and Engels, 2006). PBC is formed by control beliefs—which are beliefs about factors that may facilitate or constrain the ability to perform the behavior under consideration (Ajzen 1991; Ajzen et al., 2007; Ajzen, 2012). Prior studies have established a strong correlation between control beliefs and PBC (Armitage and Conner, 2001; Gagin and Godin, 2000; Ajzen 2012). Thus, either PBC or its proxy (control beliefs) can moderate the intention-behavior relation (Ajzen, 2012). Parental monitoring and access to cigarettes are control

beliefs that may influence smoking intention among adolescents (Bohnert et al., 2009; Spivak et al., 2015, White et al., 2005) and have been included in previous theory-based studies that examined smoking determinants among adolescents (Carvajal et al., 2004; Mcmillan et al., 2003). In addition, adolescent never-smokers have attitudes and norms toward smoking as well as background characteristics (including sociodemographic factors, risk-taking propensity, pro-tobacco and anti-tobacco media exposures) that may independently predict both smoking intention and smoking initiation (Dube et al., 2013; Farrelly et al., 2005; Lydon-Staley et al., 2018). As a result, it will be necessary to adjust for these confounders while examining how e-cigarette use moderates the association between smoking intention and smoking initiation. In fact, adequate control for confounders is recommended for studies that aim to examine the link between e-cigarette use and smoking onset (Chapman, Bareham, Maziak, 2018; Etter, 2018; Schneider et al., 2018). The current study uses a theory-guided approach to control for potential confounders while examining the moderation effect of e-cigarette use on the association between smoking intention and smoking initiation. Thus, PBC; interaction between PBC and smoking intention; control beliefs (parental monitoring and access to cigarettes); attitudes and norms toward smoking; and background characteristics will all be adjusted for in the current study.

Summary

There could be underlying explanations for the direct association between adolescent e-cigarette use and initiation of conventional cigarette smoking including the addiction risk of e-cigarette use (addiction pathway), the development of smoking

intention from e-cigarette use (smoking intention pathway), and the potential moderation of the intention-behavior relation between smoking intention and smoking initiation by e-cigarette use (intention-behavior moderation pathway). Prior studies have investigated the addiction and smoking intention pathways but empirical evidence for the intention-behavior moderation pathway is limited and findings from few existing studies are inconsistent.

Current Study

The current study focuses on exploring the potential moderation role of e-cigarette use in the association between smoking intention and smoking initiation among US adolescent never-smokers of conventional cigarettes. Specifically, the study, guided by TPB, investigates how e-cigarette use influences the progression from smoking intention to initiation of conventional cigarette smoking, while controlling for the role of perceived behavioral control over smoking, control beliefs such as parental monitoring and access to cigarettes, and other potential confounding factors The study fully elucidates the nature of the interaction between smoking intention and e-cigarette use in predicting smoking initiation in a national sample of adolescent never smokers of conventional cigarettes.

Research Question & Hypothesis

Does e-cigarette use moderate the association between smoking intention and smoking initiation among adolescents who have never smoked conventional cigarettes? If so, how? I hypothesize that e-cigarette use will moderate the prospective association between smoking intention and smoking initiation among adolescent never-smokers of

conventional cigarettes, after controlling for potential confounders such as perceived behavioral control over smoking, attitudes and norms toward smoking, and other background psychosocial predictors of adolescent smoking. The association between smoking intention and smoking initiation will differ based on e-cigarette use status, with the association stronger in e-cigarette users than never e-cigarette users.

METHODS

Study participants

Deidentified data were obtained from public-use files of the PATH study, a nationally representative cohort study of civilian, non-institutionalized US population (aged 12 years and older) (Hyland et al., 2016; United States Department of Health and Human Services, 2019). The study, launched by the National Institutes of Health and US Food and Drug Administration, used a four-stage stratified probability sample design to collect smoking-related information (Hyland et al., 2016). For youth aged 12-17 years, data were collected from both the adolescents and their parents. Parents did not constitute a separate survey sample because youth participation in PATH study was contingent upon parent/guardian's consent and completion of a brief interview about the selected youth (United States Department of Health and Human Services, 2019). Thus, all participants had their parent/guardian (N=8668) complete a brief interview which was primarily about the youth with very limited questions about parental demographics and smoking behavior. Wave 1 youth/parent data were collected from September 2013 to December 2014, wave 2 data were collected a year after wave 1 (2014-2015), and wave 3 data a year after wave 2 (2015-2016).

In the current study, only waves 2 and 3 data were used for the following reasons. First, as recommended by previous studies, intention-behavior relation is best investigated using two successive waves of data that are as close in time as possible (Topa et al., 2010; Van De Ven et al., 2006; Van den Eijnden et al., 2006). Second, later waves of data were used because of the higher prevalence of e-cigarette use in wave 2 versus wave 1, a reflection of the increased popularity of e-cigarette use in the period the data were collected (2014-2015). As a result, only participants who were adolescents (aged 12-17 years) at both waves 2 and 3 were selected. New baseline participants who were <12 years at wave 1 ("shadow youth") but aged up to become adolescents in wave 2 were also included. However, wave 2 adolescents who aged up to become adults (≥ 18 years) in wave 3 were not included (i) because of the focus of the current study on adolescents <18 years of age and (ii) because adolescents ≥ 18 years of age are considered as adults and have characteristics (e.g. legal access to cigarettes) that differ from our target adolescent population. The resulting analytic sample (N = 8668) comprises adolescents (aged 12-17 years) who had never smoked conventional cigarettes at wave 2 and were followed through wave 3 to determine their smoking outcome. The current study was determined to be non-human subjects research by the University of Texas at Austin Institutional Review Board.

Measures

Smoking initiation at wave 3 (Dependent Variable)

Participants were considered to have initiated smoking at wave 3 if they responded "yes" to the question: "In the past 12 months, have you smoked a cigarette,

even one or two puffs?" Participants who responded "no" were considered to be "never-smokers."

Smoking intention at wave 2 (Independent Variable 1)

For the purpose of this study, smoking intention is defined as intention to smoke conventional cigarettes in the next year, measured using a single item: "Do you think you will smoke a cigarette in the next year?" Responses were on a 4-point scale: 1="definitely yes" 2="probably yes" 3="probably not" 4="definitely not." Consistent with previous studies (Barrington et al., 2016b; Burnell et al., 2014; Choi et al., 2001; Wakefield et al., 2004; Owotomo et al., 2018) responses were dichotomized, with the response "definitely not" indicating firm intention not to smoke conventional cigarettes, and other responses (1="I definitely yes" 2="probably yes" and 3="probably not") suggesting intention to smoke conventional cigarettes in the near future. Contrary to previous studies that used smoking intention interchangeably with smoking susceptibility (Barrington-Trimis et al., 2016a, Owotomo et al., 2018a), or included smoking intention as a component of a broader smoking susceptibility index—comprising smoking intention, curiosity, and self-efficacy/behavioral control (Choi et al., 2001; Berry et al., 2019; Pierce et al., 2018; Soneji et al., 2017b; Strong et al., 2015), the current study made a clear distinction between smoking intention and smoking susceptibility. The smoking susceptibility index created in previous studies is a combination of several related but distinct behavioral constructs. For example, the single item "think you will smoke next year" is a validated measure of smoking intention (Choi et al., 2001; Stanton, Barnett, and Silva, 2005; Wakefield et al., 2004), and the item "would smoke cigarettes if offered by friends" is a

component of a broader PBC scale used in previous TPB studies (Devries, Dijkstra, and Kuhlman, 1988; Engels, Knibbe, De Vries, and Drop, 1998; Van De Ven et al., 2006; Van De Ven, Engels, Otten, & Van Den Eijnden, 2007). According to TPB, although related, PBC and smoking intention are two separate behavioral constructs (Topa et al., 2010), as a result, the current study defined and operationalized each of these constructs separately (Choi et al., 2001). Although the smoking susceptibility index is advantageous because it improves the identification of adolescents at risk of initiating smoking (Strong et al., 2015), operationalizing smoking intention as "intended" by the TPB may still be needed in studies (such as the current one) that aim to investigate smoking intention as a unique behavioral construct or assess its relationships with other specific constructs/predictors of adolescent smoking.

Ever e-cigarette use at wave 2 (Independent Variable 2)

Participants were asked the question: "Have you ever used an electronic nicotine product, even one or two times? (Electronic nicotine products, such as e-cigarettes, e-cigars, e-pipes, e-hookahs, personal vaporizers, vape pens and hookah pens). Those who responded "yes" were named 'e-cigarette users' and those who responded "no" were named 'never e-cigarette users.'

Covariates:

Wave 2 Background media exposures

Exposure to anti-tobacco advertisements was a composite variable formed from six dichotomous (yes/no) items. Participants were shown images representing the slogans

or themes of major antismoking campaigns (Tips campaign, Truth campaign, and Real cost campaign) and asked if they had seen or heard of them in the past 12 months. Participants were also asked if they had seen or heard of any of the following antismoking ads on television, the internet or radio in the past 12 months. "What are cigarettes costing you;" "A tip from a former smoker;" and "Cigarettes are bullies. Don't let tobacco control you." Responses to these items were "yes/no/not sure" but dichotomized into yes/no. The dichotomized responses were dummy coded and summed. Higher values indicates greater exposure to anti-tobacco advertisements.

Exposure to pro-tobacco marketing was measured by creating a composite variable from ten dichotomous (yes/no) items. First, participants were asked if they had noticed cigarettes or other tobacco products being advertised in the past 30 days in any of the following places: posters or billboards; newspapers or magazines; websites or social media sites; radio; television; and at events such as fairs, festivals, or sporting events? Participants were also asked if they have had the following experiences in the past 6 months: "seen a tobacco sweepstakes ad; gotten a discount coupon for any tobacco product; received any information other than coupons from a tobacco company; gotten a free sample of a tobacco product." Responses to these items were dummy coded and summed to create an exposure to pro-tobacco marketing index, with higher values indicating greater exposure to pro-tobacco marketing.

Wave 2 Attitudes toward conventional cigarette smoking

Perception of addictiveness of conventional cigarette smoking was measured using a single item: "How likely is someone to become addicted to cigarettes?" Response

were on a 5-point Likert scale: 1 = “very unlikely,” 2 2 = “somewhat unlikely,” 3 = “neither likely nor unlikely,” 4 = “somewhat likely,” and 5 = “very likely.”

Perception of harm of conventional cigarette smoking was measured by averaging responses from three items: “How much do you think people harm themselves when they smoke cigarettes?” “How much do you think people harm themselves when they smoke cigarettes every day?” “How much do you think people harm themselves when they smoke cigarettes some days but not every day?” Responses were on a 4-point scale: 1 = “no harm,” 2 = “little harm,” 3 = “some harm,” and 4 = “a lot of harm.” These responses were averaged such that a higher score represents higher perception of harm.

Wave 2 Subjective norms about conventional cigarette smoking

These refer to participants’ perceptions of how prevalent conventional cigarette smoking is among family/friends (descriptive norms) and whether family/friends approve or disapprove of it (injunctive norms) (Ajzen, 2012; Fishbein and Ajzen, 2010). Thus, the two distinct components of subjective norms (injunctive and descriptive norms) were measured using separate items (Rimal and Real, 2003; Rivis and Sheeran, 2003).

Parent/guardian disapproval of smoking conventional cigarettes (Injunctive norm) was measured using a single item: “If your parents or guardians found you using tobacco, how do you think they would react? Would they . . . ?” Responses were: 1 = “Be very upset,” 2 =”not be too upset,” 3= “have no reaction.” This was dichotomized such that participants who responded “no reaction” were considered to have “less disapproving injunctive norm” while those who responded “Be very upset” and “not too upset” were considered to have “more disapproving injunctive norm.”

Peer smoking (Descriptive norm) was measured using a single item: “How many of your best friends smoke cigarettes?” Responses were on a 5-point Likert scale: 1 = “none,” 2 = “a few,” 3 = “some,” 4 = “most,” and 5 = “all.”

Wave 2 Perceived behavioral control (PBC) and Control Beliefs

As explained above, PBC was measured using a single item from the PBC scale used in previous studies (Devries, Dijkstra, and Kuhlman, 1988; Engels, Knibbe, De Vries, and Drop, 1998; Van De Ven, Engels, Otten, and Van Den Eijnden, 2006; Van De Ven et al., 2007): “If one of your best friends were to offer you a cigarette, would you try it?” Responses were on a 4-point scale: 1="definitely yes" 2="probably yes" 3="probably not" 4="definitely not," but were dichotomized, with the response “definitely not” indicating high PBC and other responses (1="I definitely yes" 2="probably yes" and 3="probably not") suggesting low PBC.

Participants were also asked about access to cigarettes and parental monitoring—which are considered to be control beliefs that may influence smoking intention among adolescents as discussed above.

Access to tobacco products was measured using a single item: “How easy do you think it is for people your age to buy tobacco products in a store?” Responses on a 4-point scale: 1 = “very easy” 2 = “somewhat easy,” 3 = “somewhat difficult,” 4 = “very difficult.”

Parental monitoring was measured using parental reports on two items: “In general, does (Child's first name) have a curfew or set time that (he/she) needs to be home on school nights?” “In general, does (Child's first name) have a curfew or set time

that (he/she) needs to be home on weekend nights?" Participants were not asked these questions in the survey, so their parents' reports were used. Responses to the two items were yes/no but dummy coded and summed ($\alpha = 0.86$), with higher values indicating higher parental monitoring. These items are components of a broader parental monitoring scale used in previous studies (Dever et al., 2012).

Other tobacco product use at wave 2

A composite variable was created to adjust for other tobacco products used by participants at wave 2. Participants responded yes or no to questions on ever use of each of the following products: cigar, cigarillo, filtered cigar, pipe, hookah, smokeless tobacco, snus, dissolvable tobacco, bidi, and kretek. Responses were dummy coded and summed with higher values representing higher number of alternative tobacco product used.

Wave 2 Sociodemographic factors

Sociodemographic variables include race and ethnicity (White non-Hispanic; Black non-Hispanic; Other non-Hispanic; and Hispanic); sex (male and female); age (categorized in PATH public-use data file into 12-14 years old and 15-17 years old), and parent education level (reported by participating parent or guardian) measured via a single item: "What is the highest grade or year of school that you completed?" Parent's response: 1 = less than high school, 2 = GED, 3= high school graduate or equivalent, 4 = some college (no degree) or associates degree, 5 = bachelor's degree, 6 = advanced degree).

Statistical analysis

Multivariable logistic regression was used to analyze whether or not e-cigarette use moderates the association between smoking intention and smoking initiation among adolescent never-smokers. Model 1 had smoking intention and ever e-cigarette use at wave 2 as independent variables and smoking initiation at wave 3 as the outcome variable, without including any interaction term or covariates. For model 2, the outcome variable was smoking initiation at wave 3, independent variables were smoking intention at wave 2, ever e-cigarette use at wave 2, and interaction term (smoking intention x e-cigarette use), and covariates (including interaction term: PBC x intention, as indicated by TPB) (Ajzen, 1991; Ajzen, 2012; Schifter & Ajzen, 1985) were included. Continuous variables were mean-centered and categorical variables contrast coded (-1, 1) to avoid multicollinearity that may occur between the interaction term and the predictor variables (Dawson, 2014). However, the dependent variable was not mean-centered to avoid interpretations that will not accurately reflect the true variations in it (Dawson, 2014). Adjusted odd ratios (AORs) and 95% confidence interval (CIs) were obtained from the output of the regression model and reported accordingly. The moderation effect of e-cigarette use was determined by the coefficient of the interaction term, with a statistically significant coefficient indicating that the slope of the association between smoking intention and smoking initiation is statistically different for e-cigarette users and never e-cigarette users (Dawson, 2014; Robinson, Tomek, and Schumacker, 2013). An interaction plot was created to visualize how the slopes of the association between smoking intention and smoking initiation differed for e-cigarette users versus never e-cigarette users (Dawson, 2014; www.jeremydawson.com/slopes.htm). Simple slope tests

were further used to test how the effect of smoking intention on smoking initiation varied for each category of e-cigarette users, i.e. to assess whether the association between smoking intention and smoking initiation is statistically significant for e-cigarette users and never e-cigarette users. This was done with the direct method proposed by Dawson (2014), which involves using a combination of unstandardized regression coefficients and coefficient variances (obtained by separately requesting for a covariance matrix in the output of the regression analysis) to generate the simple effects coefficients, test statistic (t-value) and p-value for the simple slope of each e-cigarette user category (Dawson, 2014; www.jeremydawson.com/slopes.htm). The simple effects coefficients generated were then used to calculate the odds ratio for the effect of smoking intention on smoking initiation for each e-cigarette user category.

The percentage of missing data for each variable ranged from 0.01% (ever use of other tobacco products) to 8.4% (race/ethnicity). Data were assumed to be missing completely at random and were handled using complete-case analysis (listwise deletion) (Pigott, 2001). Statistical analysis was conducted using the SAS software, version 9.4 (SAS Institute, Cary, NC). As recommended, wave 3 all-waves replicate weights were applied for the analysis and Fay's variant of balanced repeated replication was used for accurate estimation of variances (Hyland et al., 2016; USDHHS, 2018b; Zinn, 2016). Statistical significance for all analyses conducted was set at $p < .05$.

RESULTS

Descriptive statistics

Adolescent never-smokers of conventional cigarettes selected for the current study were predominantly White Non-Hispanic (55.1%), males (51.4%), and aged 12-14 years (62.7%). More than a third (36.2%) of parents/guardians had at least a bachelor's degree; 21.6% reported being widowed, divorced, or separated; and 15.4% and 3.8% were past 30-day conventional cigarette smokers and e-cigarette users, respectively. See Table 4.1 for more details on sample descriptive statistics.

Table 4.1: Sample descriptive characteristics, N = 8668, weighted

		n (%)
Sex	Male	4458 (51.4)
	Female	4189 (48.6)
	Missing	21
Age	12 – 14 year olds	5488 (62.7)
	15 – 17 year olds	3180 (37.3)
Race/ethnicity	White Non- Hispanic	3928 (55.1)
	Black Non-Hispanic	1152 (14.4)
	Other Non-Hispanic	778 (10.1)
	Hispanic	2083 (20.4)
	Missing	727
Parent/guardian education	< high school	1230 (12.7)
	GED	334 (3.7)
	High school graduate	1436 (16.9)
	Some college	2488 (30.5)
	Bachelor's degree	1627 (22.7)
	Advanced degree	898 (13.5)
	Missing	617
Parent/guardian marital status	Married	5601 (65.2)
	Widowed, divorced, separated	1813 (21.6)
	Never married	1214 (13.0)
	Missing	40
Parent/guardian past 30-day tobacco use	Cigarette, cigar or pipe	
	Yes	1089 (15.4)
	No	5839 (84.6)
	Missing	1740
	Smokeless tobacco	
	Yes	114 (1.6)
	No	6815 (98.4)
	Missing	1739
	E-cigarette, hookah or dissolvable tobacco	
	Yes	270 (3.8)
	No	6659 (96.2)
	Missing	1739

Smoking-related characteristics at wave 2

At wave 2, 12.5% of participants had intention to smoke conventional cigarettes, 8.4% had ever used e-cigarettes, and 4.0% had ever used at least one other non-cigarette tobacco product (e.g. cigars, cigarillos, pipe, hookah, snus). Also, 16% of participants reported exposure to five or more different forms of pro-tobacco marketing in the prior 1-6 months, and 74.6% had seen at least one anti-tobacco ad in the prior 12 months. By wave 3, 3.4% of participants had initiated conventional cigarette smoking. See Table 4.2 for more details on smoking-related characteristics of the sample at wave 2.

Table 4.2: Smoking-related characteristics of sample at wave 2, N = 8668

	n (%)
Smoking intention at wave 2	
Yes	1110 (12.5)
No	7547 (87.5)
Missing	11
Ever e-cigarette use at wave 2	
Yes	701 (8.4)
No	7557 (91.6)
Missing	401
Ever cigarette smoking at wave 3	
Yes	276 (3.4)
No	8385 (96.6)
Missing	7
Injunctive norm toward smoking	
Parents less approving of smoking	8445 (98.5)
Parents more approving of smoking	139 (1.5)
Missing	84
Perceive behavioral control (PBC) over smoking	
Low (may smoke if friend offered cigarettes)	1283 (14.4)
High (will not smoke if friend offered cigarettes)	7374 (85.6)
Missing	11
Pro-tobacco ads exposure (number)	
0	2979 (34.5)
1	1459 (16.7)
2	1114 (12.9)
3	939 (10.8)
4	782 (8.9)
≥5	1393 (16.1)
Missing	2

Table 4.2 (continued)

Anti-tobacco ads exposure (number)	
0	2249 (25.4)
1	752 (8.4)
2	646 (7.4)
3	1556 (18.4)
4	1414 (16.0)
≥5	2048 (24.4)
Missing	3
Other tobacco products use (number)	
0	8256 (95.1)
1	336 (4.0)
2	53 (0.6)
≥3	22 (0.3)
Missing	1
	M (SE)
Peer smoking (scale 1-5)	1.23 (0.01)
Missing	62
Perceived harm of conventional cigarette smoking (scale 1-4)	3.76 (0.01)
Missing	7
Perceived addictiveness of conventional cigarette smoking (scale 1-5)	4.21 (0.01)
Missing	
Access to cigarettes in store (participants' report) (scale 1-4)	2.06 (0.01)
Missing	281
Parental monitoring (Scale 1-3)	1.70 (0.01)
Missing	35

Multivariable regression models

In model 1 (Table 4.3), without an interaction term and covariates, smoking intention at wave 2 was directly associated with smoking initiation at wave 3 (OR = 2.23, 95% CI = 1.90 – 2.61, p<.001). Ever e-cigarette users at wave 2 had 1.90 (95% CI = 1.59 – 2.26, p<.001) times the odds of initiating cigarette smoking at wave 3 compared with never e-cigarette users. In model 2, after including the interaction term and covariates (Table 4.3), both smoking intention and ever e-cigarette use at wave 2 were directly associated with smoking initiation at wave 3 (Adjusted odds ratio, [AOR] = 1.33; 95% CI = 1.05 – 1.69, p <.05; AOR = 1.65; 95% CI = 1.37 – 2.00, p <.001, respectively), and the

interaction between smoking intention and ever e-cigarette use at wave 2 was also statistically significant (AOR = 0.76; 95% CI = 0.64 – 0.90, p <.01). Also in model 2, PBC, peer smoking, and use of non-cigarette tobacco products at wave 2 were directly associated with ever cigarette smoking at wave 3. Adolescent never-smokers who had low PBC were more likely than those with high PBC to have initiated cigarette smoking at wave 3 (AOR = 1.57, 95% CI = 1.30 – 1.89, p <.001). Also, the odds of smoking initiation in wave 3 was higher among participants who used non-cigarette tobacco products or had more friends who smoked cigarettes at wave 2 (OR = 1.40, 95% CI = 1.06 – 1.86, p <.05; OR = 1.40, 95% CI = 1.13 – 1.73, p <.01, respectively). The interaction between PBC and smoking intention was not statistically significant.

Table 4.3: Adjusted multivariable logistic regression showing interaction between smoking intention and ever e-cigarette use at wave 2 in prediction of ever cigarette smoking at wave 3 (*N*= 6672)

	Smoking initiation at wave 3					
	Model 1			Model 2		
	B (SE)	OR	95% CI	B (SE)	AOR	95% CI
Smoking Intention (Referent =No)						
Yes	0.80 (0.08)	2.23***	1.90 – 2.61	0.28 (0.12)	1.33***	1.05 – 1.68
Ever e-cigarette use (Referent = No)						
Yes	0.64 (0.08)	1.90***	1.59 – 2.26	0.51 (0.10)	1.67***	1.38 – 2.03
Smoking intention x e-cigarette use				-0.28 (0.9)	0.76**	0.64 – 0.90
PBC (Referent = high)						
Low (may smoke if friend offered cigarette)			---	0.45 (0.10)	1.56***	1.30 – 1.89
PBC x smoking intention			---	0.03 (0.12)	1.04	0.82 – 1.34
Injunctive norm (referent = less approving)						
More approving			---	0.11 (0.33)	1.12	0.59 – 2.13
Descriptive norm (peer smoking)			---	0.34 (0.11)	1.40**	1.13 – 1.73
Perceived harm of smoking cigarettes			---	-0.25 (0.19)	0.78	0.54 – 1.14
Perceived addictiveness of cigarette smoking			---	0.04 (0.08)	1.04	0.90 – 1.21
Access to cigarettes at store			---	-0.03 (0.10)	0.98	0.80 – 1.20
Parental monitoring				0.13 (0.14)	1.14	0.86 – 1.49
Pro-tobacco ads exposure			----	0.05 (0.03)	1.05	0.98 – 1.11
Anti-tobacco ads exposure				0.02 (0.04)	1.02	0.94 – 1.09
Other tobacco product use				0.34 (0.14)	1.40*	1.06 – 1.86
Race/ethnicity (Referent = White Non-Hispanic)						
Black Non-Hispanic				-0.55 (0.15)	0.58***	0.43 – 0.78

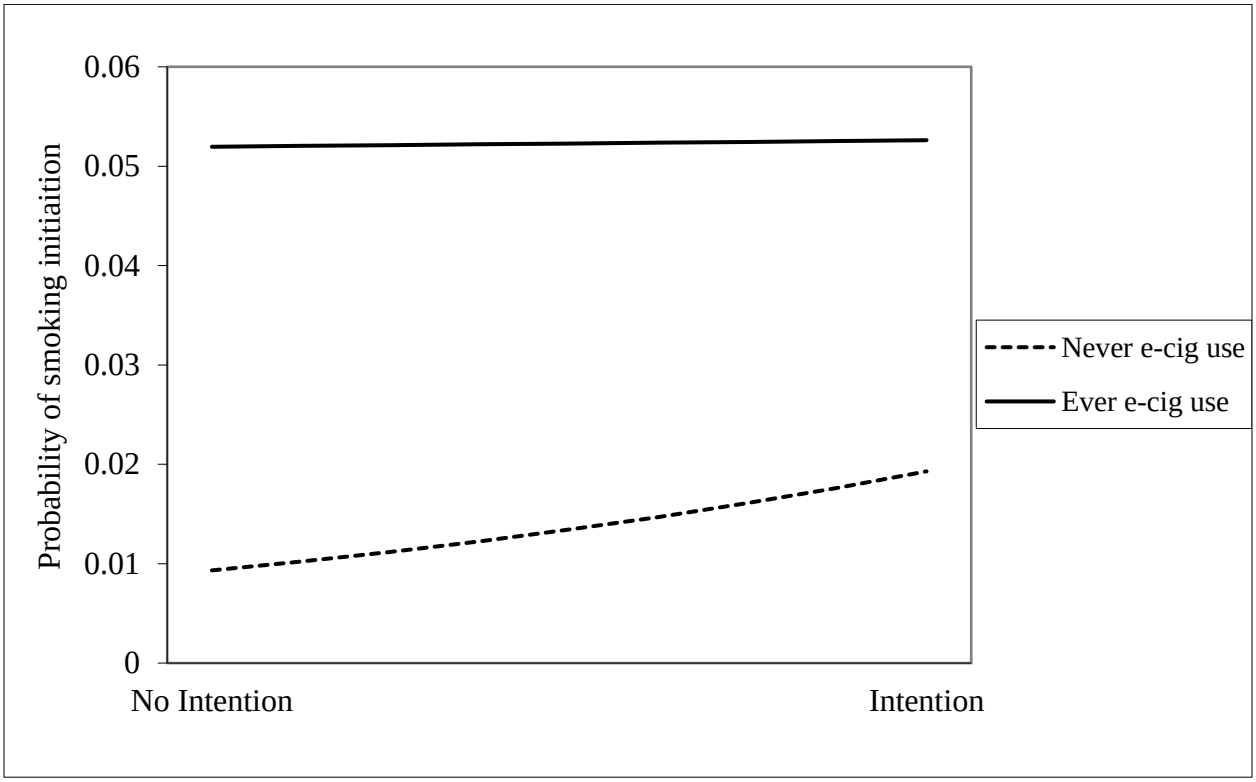
Table 4.3 (continued)

Other Non-Hispanic	-0.18 (0.14)	0.83	0.63 – 1.11
Hispanic	-0.40 (0.10)	0.67***	0.55 – 0.83
Sex (Referent = female)			
Male	0.01 (0.08)	1.01	0.86 – 1.18
Age (Referent = 15 -17 years)			
12 – 14 years	-0.05 (0.08)	0.95	0.82 – 1.11
Parent/guardian education	-0.14 (0.06)	0.87*	0.77 – 0.98

****p<.001; **p<.01; *p<.05; OR: Adjusted Odds Ratio; CI: Confidence Interval. SE: Standard Error*

Figure 4.1 graphical depicts the interaction between smoking intention and e-cigarette use, showing that the association between smoking intention and smoking initiation is different for ever e-cigarette users and never e-cigarette users. Results of the simple slope tests show that the association between smoking intention and smoking initiation was statistically significant among never e-cigarette users, (b = 0.55, t = 4.73, p <.001) but not statistically significant among ever e-cigarette users (b = 0.01, t = 0.06, p = 0.95). Among adolescent never e-cigarette users, the odds of progressing to smoking initiation was higher among those who had smoking intention compared with those who had no intention to smoke (OR = $e^{0.55}$ = 1.50, p <.001, calculated odds ratio from the simple effect coefficient) (Newsom, 2016). Among adolescent e-cigarette users, the odds of progressing to smoking initiation was not different for those who had smoking intention and those who had no intention to smoke (OR = $e^{0.01}$ = 0.03, p >.05).

Figure 4.1: Plot depicting moderating effect of e-cigarette use on the association between smoking intention and smoking initiation (intention-behavior relation)



DISCUSSION

The current study employed a theory-based approach to investigate whether and how e-cigarette use moderates the relationship between smoking intention and smoking initiation among adolescent never-smokers of conventional cigarettes. It examined how e-cigarette use influences the intention-behavior relation between smoking intention and smoking initiation as operationalized in TPB. Consistent with prior studies, smoking intention and e-cigarette use were found to be independent predictors of smoking initiation. Indeed, as hypothesized, e-cigarette use moderated the relationship between smoking intention and smoking initiation, an indication that the progression from

smoking intention to smoking initiation was dependent on e-cigarette use status. However, contrary to the study hypothesis, smoking intention predicted smoking initiation only among adolescent never e-cigarette users. Never e-cigarette users who had smoking intention were more likely than those with no intention to have initiated smoking at follow up. Among e-cigarette users, smoking intention did not predict smoking initiation—suggesting that adolescent e-cigarette users were at risk of progressing to smoking initiation regardless of their smoking intention status at baseline. Overall, the study yields the following important findings: 1) the association between smoking intention and smoking initiation was dependent on e-cigarette use status; 2) smoking intention predicted smoking initiation among adolescent never e-cigarette users but not among e-cigarette users; and 3) adolescents with least likelihood of initiating smoking lacked smoking intention and were never e-cigarette users.

The association between smoking intention and smoking initiation was dependent on e-cigarette use status. While progression from smoking intention to smoking initiation (intention-behavior relation) was validated among adolescent never e-cigarette users, smoking intention lacked predictive power among adolescent e-cigarette users. Prior studies have reported that the predictive power of smoking intention varies among adolescent subgroups (Stanton et al., 2005; Wakefield et al., 2004). For example, Stanton et al (2005) found that smoking intention was an important predictor of future smoking only among adolescents who had never smoked conventional cigarettes. Among adolescents who had already tried smoking, prior smoking behavior was found to be a better predictor of future smoking than smoking intention. The current study extends the

literature by establishing, using a national sample of adolescent never-smokers, that the predictive power of smoking intention on smoking initiation among adolescent never-smokers is dependent on e-cigarette use status. Indeed, smoking intention predicted smoking initiation among adolescent never e-cigarette users but not among e-cigarette users.

Smoking intention did not predict smoking initiation among adolescent e-cigarette users. The risk of progressing to smoking initiation was same for adolescent e-cigarette users who had smoking intention and those who had no intention to smoke. Consistent with prior studies (Barrington_Trimis et al., 2016a), adolescent e-cigarette users who lacked smoking intention remained at high risk of progressing to smoking initiation. This indicates that having smoking intention is not a prerequisite to smoking initiation among adolescent e-cigarette users in current tobacco landscape. Although lack of smoking intention is an established protective factor against smoking initiation among adolescents (Wakefield et al., 2004), current evidence suggests that adolescent e-cigarette users can progress to smoking initiation even without having smoking intention. Thus, the influence of e-cigarette use on smoking initiation may potentially override the protective effect of lack of smoking intention. Future research will be needed to identify potential mechanisms underlying progression to smoking initiation among adolescent e-cigarette users who have no intention to smoke at baseline. However, current study findings may be instructive for future smoking prevention research. Because smoking intention is a well-established predictor of smoking initiation among adolescents (Topa et al., 2010), behavioral theories (such as TPB) that utilized smoking intention as a central construct

may need to be revalidated or modified to reflect the changing tobacco environment. For example, in view of the finding that e-cigarette use predicts smoking initiation even among adolescents who have no smoking intention, future theory-based studies aiming to explain adolescent smoking behavior should consider operationalizing e-cigarette use as a stand-alone construct or examine how e-cigarette use may interact with established behavioral constructs to predict smoking initiation among adolescents.

Further, abstinence from e-cigarette use, coupled with lack of smoking intention, was the major protective factor against smoking initiation in the current national sample of adolescent never-smokers. Adolescents who had never used e-cigarettes and had no intention to smoke conventional cigarettes were the least likely to have progressed to smoking initiation. These findings suggest that abstinence from e-cigarette use and lack of smoking intention are concurrently needed to prevent or delay smoking initiation among adolescents in the current tobacco landscape. Therefore, tailored interventions that prevent adolescents from developing smoking intention and emphasize abstinence from e-cigarette use may be effective in preventing smoking initiation among today's adolescents. Indeed, abstinence from e-cigarette use should be framed as an adolescent smoking prevention strategy in the current tobacco context.

The study also yielded other significant findings regarding factors influencing progression from e-cigarette use to conventional cigarette smoking. Consistent with TPB (Ajzen, 1991, Ajzen et al., 2007), PBC predicted smoking initiation, suggesting that adolescents who had lower capabilities to refuse smoking when the opportunity arose were more likely to progress to smoking initiation. A practical implication of this finding

is the need to teach refusal skills to adolescents as a component of a broader smoking prevention program. The interaction between PBC and smoking intention was not significant (suggesting that the association between PBC and smoking initiation is not depend on smoking intention), which is also consistent with findings from previous studies. According to Ajzen (1991), of seven studies that tested the hypothesis that behavioral intention and PBC should interact to predict behavior, only one study found a marginally significant interaction (Schifter & Ajzen, 1985). Therefore, the importance of PBC in moderating the intention-behavior relation should be revisited in future research. Descriptive norm (peer smoking) was also a significant predictor of smoking initiation at follow up, which is consistent with findings from previous TPB studies (Rivis et al., 2003), and may be a factor influencing progression from e-cigarette use to conventional cigarette smoking. Similarly, higher number of non-cigarette tobacco product used by participants was associated with the increased risk of progressing to smoking initiation. Polytobacco use can predispose adolescents to nicotine addiction and other risks associated with tobacco use (Harrell, Nagvi, Plunk, Ji, and Martins, 2017; King et al., 2018). Therefore, adolescents should be discouraged from using all forms of tobacco products.

Limitations

Study was limited by survey measures. For example, a measure for sensation seeking was lacking in the wave 2 data, as a result, sensation seeking, an important predictor of smoking initiation, was not adjusted for in the regression model. Also, the measure for parental monitoring was based on parent-report and did not capture

adolescent disclosure component of parental monitoring (Stattin and Kerr, 2000), which may limit the interpretation of its association with smoking initiation. Another limitation was the relatively long interval between the study waves. Prior studies have suggested that intention-behavior relation yield stronger associations when tested as close in time as possible e.g. 3 or 6 months (Topa et al., 2010). Because this was an annual longitudinal study, it is possible that adolescents may have developed smoking intention and progressed to smoking initiation between the waves of data collection i.e. the year-long gap between study waves may be too long to accurately capture the development of smoking intention. Thus, findings from this study will need to be validated in cohort studies with shorter wave intervals. Nonetheless, the large nationally representative sample is a major strength of this study which allows our findings to be generalizable to the US adolescent never-smoker population. Finally, the study was conducted during 2014-2016, before JUUL e-cigarettes (with high addictive potential) gained popularity among adolescents, thus more recent studies may provide additional evidence for the addiction pathway that potentially underlies progression from e-cigarette use to conventional cigarette smoking.

Conclusion

The intention-behavior moderation pathway provides a potential explanation for the progression from e-cigarette use to conventional cigarette smoking among adolescents. E-cigarette use was found to moderate the association between smoking intention and smoking initiation (intention-behavior relation) among adolescent never-smokers of conventional cigarettes. The intention-behavior relation was different for e-

cigarette users and never e-cigarette users, such that smoking intention did not predict smoking initiation among adolescent e-cigarette users but remained a predictor of smoking initiation among adolescent never e-cigarette users. The findings suggest that adolescent e-cigarette users are at heightened risk of initiating conventional cigarette smoking regardless of their background smoking intention. A combination of abstinence from e-cigarette use and lack of smoking intention was found to be the major protective factor against smoking initiation in the current national sample of adolescent never-smokers. Overall, abstinence from e-cigarette use was a protective factor against smoking initiation, particularly among adolescent never e-cigarette users who had no intention to smoke. Tailored interventions that prevent adolescents from developing smoking intention and emphasize abstinence from e-cigarette use may be effective in preventing smoking initiation among today's adolescents. Future theory-based studies aiming to explain adolescent smoking behavior should consider the role of e-cigarette use and the rapidly changing tobacco environment.

Chapter 5: Conclusion and Overall Implications

The dissertation was informed by identified gaps in existing literature surrounding adolescent e-cigarette use. While robust evidence exists to support adolescent e-cigarette users' progression to conventional cigarette smoking, little work has been done to unravel the underlying factors that may be responsible for this progression. Guided by the Theory of Planned Behavior, this dissertation aimed to identify some potential factors that may underlie the progression from e-cigarette use to conventional cigarette smoking among US adolescents. The three studies of this dissertation revealed unique characteristics of adolescent e-cigarette users that may increase their risk of progressing to conventional cigarette smoking. The studies also identified how e-cigarette use influences the progression from smoking intention to smoking initiation among adolescent never-smokers.

From study 1, I identified adolescent e-cigarette users' smoking-related background factors (risk-taking propensity and perceived influence of antismoking ads), and attitudes and norms toward smoking (absolute smoking-related perceptions—perceived harm and addictiveness of conventional cigarette smoking; and peer smoking). I concluded from the study findings that adolescent e-cigarette users share similar characteristics with conventional cigarette smokers—they have similar absolute cigarette harm perceptions, risk-taking propensity, and number of peers who smoke with conventional cigarette smokers. However, adolescent e-cigarette users lack some protective features that non-users of tobacco products have—they have lower cigarette addiction perceptions, they have been less influenced by antismoking ads, and have

higher risk-taking propensity than non-users. These unique characteristics of adolescent e-cigarette users heighten their risk of initiating conventional cigarette smoking.

From study 2, I identified distinct subgroups of adolescent e-cigarette users that differ based on key predictors of smoking including background pro-and anti-tobacco media exposures, risk-taking propensity, attitudes and norms toward conventional cigarette smoking, and control beliefs over smoking (access to cigarettes and parental monitoring). I concluded from the study findings that there are three distinct subgroups of adolescent e-cigarette users with each having particular smoking-related characteristics that determine exhibition of smoking intention. Adolescent e-cigarette user subgroup at most risk of exhibiting smoking intention has an imbalanced combination of risk and protective factors for conventional cigarette smoking--including negative attitudes and norms toward smoking, low parental monitoring, and high access to conventional cigarettes.

From study 3, I found that e-cigarette use moderated the association between smoking intention and smoking initiation. Progression from smoking intention to smoking initiation is dependent on e-cigarette use status. Among adolescent never e-cigarette users, smoking intention predicted smoking initiation. However, contrary to expectations from TPB, smoking intention was not associated with smoking initiation among adolescent e-cigarette users. I concluded from the study findings that adolescent e-cigarette users are at risk of progressing to smoking initiation whether or not they exhibit smoking intention, an indication that the influence of e-cigarette use on smoking initiation may potentially override previous protective factors against smoking initiation

such as lack of smoking intention. Also, I found that adolescents least likely to initiate conventional cigarette smoking in the current tobacco landscape do not have the intention to smoke and are abstaining from e-cigarettes.

The three studies together highlighted factors that may potentially underlie the progression from e-cigarette use to conventional cigarette smoking among adolescent e-cigarette users. These factors include background factors (low perceived influence of antismoking ads, high risk-taking propensity), negative attitudes and norms toward conventional cigarette smoking, high access to cigarettes, and low parental monitoring. In addition, adolescent e-cigarette users defy the intention-behavior relation of TPB, such that e-cigarette use directly predicts smoking initiation independent of background smoking intention. Among adolescent e-cigarette users, lack of smoking intention is not protective against progression to smoking initiation.

Findings from the three studies are summarized as follows. First, adolescent e-cigarette users are at heightened risk of progressing to conventional cigarette smoking because they have risk factors that have been historically linked to conventional cigarette smoking among adolescents—lowered perceptions of harm and addictiveness of conventional cigarette smoking, high number of friends who smoke cigarettes and few who disapprove of smoking, high access to cigarettes, and low parental monitoring. Second, the subgroup of adolescent e-cigarette users at most risk of smoking conventional cigarettes also exhibit some of the aforementioned smoking-related characteristics including negative attitudes and norms toward smoking, low parental monitoring, and high access to conventional cigarettes. Third, smoking intention predicts

smoking initiation only among adolescent never e-cigarette users. Among adolescent e-cigarette users, smoking intention does not predict smoking initiation, an indication that an adolescent e-cigarette user may progress to smoking initiation regardless of background smoking intention. Finally, adolescents who have never used e-cigarettes and have no intention to smoke conventional cigarettes are the least likely to progress to smoking initiation in the current tobacco landscape. These adolescents do not have the risk factors for conventional cigarette smoking that are associated with e-cigarette users; and the protective effect of lack of smoking intention on smoking initiation is preserved by their abstinence from e-cigarettes.

Overall Implications

The findings from this dissertation may be instructive for future smoking prevention research and interventions geared toward adolescent e-cigarette users.

Future research

A major future research direction will be to investigate whether the risk factors for conventional cigarette smoking among adolescent e-cigarette users, identified in this dissertation, existed before their e-cigarette use or resulted from it. Findings from such research will provide additional insights into the mechanisms involved in the progression from e-cigarette use to conventional cigarette smoking. Investigating how e-cigarette use suppresses or overrides protective factors against smoking is an important research area for future consideration.

Study 2 should be replicated using a longitudinal sample so as to identify adolescent e-cigarette user subgroup that progresses to conventional cigarette smoking. In

fact, more person-centered studies are needed to identify clusters of adolescent e-cigarette users with shared smoking-related characteristics. This will be very useful in informing intervention efforts. In addition, behavioral theories (such as TPB) that were previously applicable to the entire adolescent smoking population may need to be revalidated or modified to accommodate newer developments in adolescent smoking behavior and tobacco environment. Such studies may consider e-cigarettes as stand-alone construct or examine its interaction with other constructs. Finally, the study findings indicate that more research, particularly person-centered longitudinal studies, is needed to fully elucidate the underlying factors and processes involved in the initiation of conventional cigarette smoking among adolescent e-cigarette users.

Interventions

Given that the risk factors for conventional cigarette smoking among adolescent e-cigarette users are similar to those known to be generally associated with adolescent smoking, comprehensive smoking prevention interventions with components that address each of the identified risk factors may be effective in discouraging progression from e-cigarette use to conventional cigarette smoking. These measures are already in place and could be a reason why the much anticipated reversal in adolescent smoking rates has not occurred despite the rising prevalence of e-cigarette use. However, existing tobacco control interventions (e.g. educational campaigns that address smoking-related perceptions) should be tailored to the adolescent e-cigarette user population. Also, tailoring of smoking prevention interventions to adolescent never e-cigarette users may be necessary. For example, adolescent never e-cigarette users may benefit more from

interventions that emphasize abstinence from e-cigarette use, in addition to other prevention programs aimed to discourage smoking intention. Indeed, abstinence from e-cigarette use should be framed as an adolescent smoking prevention strategy in the current tobacco context.

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