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**Understanding Patterns of Electronic Nicotine Delivery Systems use among Young Adults**

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**Understanding Patterns of Electronic Nicotine Delivery Systems use among  
Young Adults**

**by**

**Deepti Agarwal**

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## **Dedication**

Dedicated to my late grandfather Prakash Chandra Agarwal and my late mother Jyoti Agarwal

# **Understanding Patterns of Electronic Nicotine Delivery Systems use among Young Adults**

by

Deepti Agarwal (PhD)

The University of Texas at Austin, 2021

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Research is lacking on patterns of young adult current (i.e., past 30-day) ENDS use. The aim of this dissertation was to examine 1) latent classes of young adult current ENDS users and common characteristics of young adults in these classes, and 2) if latent class membership predicted subsequent ENDS use behaviors among a cohort of young adults in Texas. For Study 1, participants were 463 young adults aged 19-31 years, drawn from wave 4 (April-May 2016) of the Marketing and Promotions across Colleges in Texas project (Project M-PACT). Latent Class Analysis using six indicator variables was conducted to discern classes of young adult current ENDS users. For Study 2, participants were 424 young adults who participated in Study 1 and had complete data on wave 6 (April-May 2017). The Study 2 hypotheses tested if classification in the highest risk class predicted subsequent current ENDS use, ENDS nicotine dependence symptoms, and using ENDS more frequently one year later. Logistic and multiple regression analyses were used to test the Study 2 hypotheses. Findings from Study 1 identified three distinct classes of users, including non-nicotine dependent social ENDS users, high-

risk poly-tobacco and substance users, and nicotine dependent ENDS users. Classes varied on sex, race/ethnicity, age, type of college attended, and current use of other tobacco products. Findings from Study 2 confirmed the hypothesis that membership in the highest risk class of high-risk poly-tobacco and substance users elevated risk for subsequent current ENDS use, ENDS nicotine dependence symptoms, and using ENDS more frequently one year later, compared to the lowest risk class of non-nicotine dependent social ENDS users, after accounting for covariates. Findings also confirmed the hypothesis that membership in the highest risk class of high-risk poly-tobacco and substance users also elevated risk for subsequent ENDS nicotine dependence symptoms and frequency of ENDS use one year later, compared to the nicotine dependent ENDS users, after accounting for covariates. Results underscore the heterogeneity among young adult current ENDS users and the need for development of distinct tobacco control messaging and intervention strategies tailored to different classes of young adult ENDS users.

## Table of Contents

Chapter 1: Introduction.....	8
Understanding patterns of Electronic Nicotine Delivery Systems use among young adults	
Chapter 2: Literature Review.....	20
Understanding patterns of Electronic Nicotine Delivery systems use among young adults	
Chapter 3: Methods.....	40
Chapter 4: Study 1.....	53
Characterizing young adult Electronic Nicotine Delivery System users	
Chapter 5: Study 2.....	78
Young adult current Electronic Nicotine Delivery System (ENDS) user latent classes prospectively predict ENDS use one year later	
Chapter 6: Conclusion.....	99
References.....	105

## **Chapter 1: Introduction**

### **Understanding patterns of Electronic Nicotine Delivery Systems use among young adults**

Young adulthood or the developmental period between 18-29 years is characterized by transitions in various life domains and behaviors including initiation of tobacco products, transition to heavy tobacco use, and quitting (Arnett & Tanner, 2016; Rath, Villanti, Abrams, & Vallone, 2012). Almost all tobacco use is initiated and regular tobacco use is established by the end of this developmental period (USDHHS., 2012). Young adults have the highest prevalence of nicotine and tobacco use (Hu, 2016) and cigarettes are still the most used tobacco product by young adults with approximately 13.1% of young adults in the United States (U.S) currently using cigarettes in 2016 (Jamal et al., 2018). However, the prevalence of cigarette smoking has been on a steady decline from 2005-2016 (Jamal et al., 2018). At the same time, there has been a steady increase in the use of Electronic Nicotine Delivery Systems (ENDS) from 2014-2018, and young adults report the highest prevalence of ENDS use among all adults (Dai & Leventhal, 2019a; Kasza et al., 2017) with 7.6% currently using ENDS in 2018 (Dai & Leventhal, 2019a).

About 2.8 million young adults aged 18-24 years were current ENDS users in 2016 (Mirbolouk et al., 2018), which is concerning given the risks of addiction from nicotine as well as added toxicants (Abbasi, 2016; Badea et al., 2018; Etter & Bullen, 2011; Etter, Zäther, & Svensson, 2013; Farsalinos, Kistler, Gillman, & Voudris, 2014; Grana, Benowitz, & Glantz, 2014; Hawk & Maresso, 2019; Khlystov & Samburova, 2016; Schroeder, 2018; Williams, Derrick, Liebman, LaFleur, & Ribisl, 2018; Yu et al., 2018). As these products are relatively new, there is also no firm conclusion on the long-term health consequences of using ENDS (Etter et al., 2013; Farsalinos et al., 2014; Grana et al., 2014). Further, the regulations around ENDS products were recently passed in August 2016 (Abbasi, 2016), and are not yet fully implemented (Yu et al., 2018).

Thus, there continues to be concerns regarding variability in the sales of ENDS and product constituents (Hawk & Maresso, 2019; Schroeder, 2018; Williams et al., 2018). Yet, despite the increasing popularity of ENDS and the health concerns associated with ENDS use, little is known about patterns of ENDS use among young adults. In particular, there is limited information about the characteristics of various patterns/classes of young adult current ENDS users and how they differ. There is also no research prospectively examining if these ENDS use patterns predict subsequent ENDS use behaviors.

*Low-volume smoking is on the rise, but little is known about volume of ENDS use*

Although we know little about patterns of ENDS use among young adults, there is a sizeable literature base examining cigarette use patterns that we can draw from to inform our understanding of ENDS use patterns. A key change in the tobacco use behaviors of 18-29 year old young adults is the shift towards low-volume smoking patterns (Schane, Glantz, & Ling, 2009a). In particular there has been a shift towards social smoking, a very prevalent sub-pattern of low-volume smoking with 80% of smokers reporting as being social smokers (Jiang, Lee, & Ling, 2014; Lisha, Delucchi, Ling, & Ramo, 2015; Moran, Wechsler, & Rigotti, 2004; Rath et al., 2012; Song & Ling, 2011). Low-volume smoking has been conceptualized as non-daily or occasional cigarette smoking or smoking on some days but not every day (Schane et al., 2009a), but can also include intermittent or light smoking and very light smoking [(usually defined as 5 or fewer cigarettes per day); (Li, Holahan, & Holahan, 2015; Pierce, White, & Messer, 2009)]. Social smoking, commonly conceptualized as smoking mainly in social situations (Moran et al., 2004) can be considered a sub-pattern of low-volume smoking.

Irrespective of the varying definitions, low-volume smoking is still concerning because there is evidence of symptoms of nicotine dependence after even a very low level of cigarette

consumption such as less than 2 cigarettes per day (DiFranza et al., 2007). Further, non-daily cigarette use patterns can be stable throughout young adulthood (Caldeira et al., 2012), which could imply that young adult low-volume smokers including social smokers, may not be quitting cigarettes and thereby sabotaging tobacco control efforts. Lastly, low-volume cigarette users may not be fully aware of the health consequences of even occasional tobacco use and they may not even identify themselves as smokers (Berg et al., 2010; Hoek, Maubach, Stevenson, Gendall, & Edwards, 2013; Levinson et al., 2007; Ridner, Walker, Hart, & Myers, 2010), which in turn may make them less susceptible to tobacco control efforts.

Although attention has been given to changing patterns of cigarette use including low-volume cigarette use patterns among young adults, very little attention has been given to patterns of ENDS use among young adults, especially low-volume patterns of use over a period of time. From what we gather from the cigarette literature and given the shift towards low-volume cigarette use patterns among young adults (Schane et al., 2009a), there is the possibility that low-volume ENDS use is also a popular pattern among young adults. Indeed, data from the 2014 Minnesota Adult Tobacco Survey indicate that among adult smokers who also indicate using ENDS in the past 30 days, more than half (59%) reported using ENDS infrequently or used ENDS  $\leq 5$  days in the past 30 days (Amato, Boyle, & Levy, 2016). Among the remaining, 28.7% reported intermediate ENDS use or use on 6-29 days in the past 30 days and only 12.3% reported daily use of ENDS in the past 30 days (Amato et al., 2016). Thus, evidence indicates that most of today's adult current ENDS users (including young adult users) also tend to be low-volume ENDS users. Yet, we know little about characteristics and other existing patterns of ENDS use among young adults and if, like low-volume cigarette use, low-volume ENDS use will remain stable over time or if low-volume users quit using ENDS over time.

### *ENDS use as a social behavior*

To understand ENDS use patterns among young adults, it is important to consider ENDS use as a social behavior and one that contributes to building a young adult's social image (Kong, Morean, Cavallo, Camenga, & Krishnan-Sarin, 2014). There is evidence that young adults see ENDS as something that can have a positive social impact (Wallace & Roche, 2018) and that ENDS can play a role in positive social enhancement. That is, young adults perceive that these products facilitate social respect, popularity, liking by peers, as well as help people enjoy social interactions more (Hendricks & Brandon, 2008; Piñeiro et al., 2016; Pokhrel, Little, Fagan, Muranaka, & Herzog, 2014). It is possible then that some of today's young adult ENDS users in addition to being low-volume users, may also be social ENDS users, a sub-group who like social smokers potentially use ENDS exclusively in social contexts (Shiffman et al., 2015). However, despite the increasing popularity of ENDS (USDHHS, 2014), research is lacking on characteristics and patterns of young adult ENDS use. To fill the gaps in existing research, my dissertation 1) identified latent classes of young adult current ENDS users as well as determined common characteristics of young adults in these classes, and 2) determined if the latent class membership predicted subsequent current ENDS use, ENDS nicotine dependence symptoms, and frequency of ENDS use one year later.

### *Assessing social ENDS use*

Although social ENDS use may be an important factor in identifying classes of ENDS users, we cannot only ask young adults to self-identify as social ENDS users. This is because self-identifying as a social ENDS user may not accurately capture the behavior. That is, research has found discrepancies between young adults who identify themselves as social smokers but do not behave as such, that is, they do not use cigarettes mainly or only in the company of others, are not

light smokers, and show higher symptoms of nicotine dependence compared to social smokers who behave as such (Lisha et al., 2015). At the same time, other research has found that young adult's self-identification as a social smoker is indeed important to examine, since more than half (57%) of social smokers also self-identified as social or occasional smokers, and 66% of social smokers also indicated smoking mainly or only with others. Moreover, self-identification as a social smoker has been found to be a key indicator that distinguishes social smokers from other smokers and non-smokers (Villanti et al., 2017). Taken together, it is possible that there are other factors in addition to self-identifying as a social ENDS user that together capture young adults' patterns of ENDS use, which has not been explored in existing research.

We can again draw upon existing research on low-volume and social smoking to identify other factors that help us understand classes of ENDS users. For instance, young adult social smokers who also behave as such generally tend to smoke fewer cigarettes per day or less than half a pack of cigarettes per day compared to those who only identify themselves as social smokers but do not behave as such (Lisha et al., 2015; Moran et al., 2004). Further, social smoking is characterized by non-daily smoking and also inversely associated with nicotine dependence (Moran et al., 2004). It is possible then that these social ENDS users like social smokers, may use ENDS infrequently, or up to 5 days in the past 30 days (Amato et al., 2016; Coleman et al., 2017; Pulvers et al., 2015).

Given that ENDS use is a social behavior (Kong, Morean, Cavallo, Camenga, Krishnan-Sarin, et al., 2014; Piñeiro et al., 2016; Pokhrel et al., 2014) and the high prevalence of low-volume ENDS use among young adults (Amato et al., 2016), I expected social ENDS use to potentially emerge as one of the set of distinct classes of current ENDS users. However, I also examined potential heterogeneity within this class. Evidence from the cigarette research indicates that there

are a group of individuals who are social smokers and also identify and behave as light smokers, that is, they report smoking, on average, less than 5 cigarettes per day, less than 5 days per week (Lisha et al., 2015). These individuals may still exhibit lower symptoms of nicotine dependence, compared to the another group of social smokers who identify themselves as social smokers as well but are not light smokers, that is they report on average using 10.22 cigarettes per day, on about 6.34 days per week, and report higher nicotine dependence (Lisha et al., 2015). Thus, there is evidence that social smokers can vary in their intensity of cigarette use, including number of cigarettes per day, number of days in a week, and nicotine dependence. Therefore, given existing evidence, there could exist at least two distinct classes of social ENDS users, addicted social ENDS users who use ENDS more frequently and also exhibit ENDS nicotine dependence symptoms and non-addicted social ENDS users who use ENDS less frequently and do not exhibit ENDS nicotine dependence symptoms.

In addition to the two social ENDS use classes, there may also exist at least two distinct classes of non-social ENDS users; addicted non-social ENDS users and non-addicted non-social ENDS users. Non-social ENDS users are individuals who do not identify as social ENDS users and thus, do not limit ENDS use to social contexts. It is likely that there is a class of addicted non-social ENDS users who do not self-identify as social ENDS users, use ENDS more frequently, and also exhibit ENDS nicotine dependence symptoms. In contrast, non-addicted non-social ENDS users are likely to also not self-identify as social ENDS users, but they use ENDS less frequently and they do not exhibit ENDS nicotine dependence symptoms. It is important to note that there may also be other ENDS user classes that may emerge from the study data, something this dissertation sought to explore. Nonetheless, understanding the heterogeneity and various classes

of current ENDS users is important as this information is critical for existing research to develop tailored tobacco control strategies specific to various classes of ENDS users.

In addition to self-identifying as a social ENDS user, frequency of ENDS use, and ENDS nicotine dependence symptoms, there are some other factors that need to be taken into account while assessing classes of current ENDS users based on existing evidence from research on cigarettes. For instance, research indicates that social smokers are more likely than non-social smokers to co-use cigarettes, alcohol, hookah, and marijuana (Lisha et al., 2015; Villanti et al., 2017). Based on this research, it is likely that all classes of social ENDS users may be more likely than the non-social ENDS user classes to be current users of other substances. Similarly, compared to daily “smokers,” those who identify as nondaily/light /“social smokers” (who used 1-10 cigarettes per day) are more likely to report using other tobacco products such as chewing tobacco and dip/snuff in the past 30 days (Villanti, Pearson, Cantrell, Vallone, & Rath, 2015). It is also possible then that the young adult social ENDS user classes are more likely than the non-social ENDS user classes to binge drink, use marijuana, and use cigarettes compared to other classes of current ENDS users.

In summary, there may emerge at least four distinct classes of current ENDS users based on factors such as self-identifying as a social ENDS user, frequency of ENDS use, ENDS nicotine dependence symptoms, binge alcohol use, marijuana use, and current cigarette use. Given these factors, I expected there to be two distinct classes of social ENDS users, and two distinct classes of non-social ENDS users.

### *Covariates of ENDS use*

Identifying classes of current ENDS users is an important step in extending the current research on young adult ENDS use. However it is also important to identify covariates of current ENDS user classes, and how various classes vary based on factors such as socio-demographics and current other tobacco use (i.e., cigars, hookah, and smokeless tobacco use). We also can draw upon existing research on low-volume and social smoking to understand socio-demographic correlates of social ENDS use, including age, sex, race/ethnicity, and type of college. Existing research has found that younger people (mean age 30) and females are more likely to report light smoking or smoking less than 5 cigarettes per day, compared to older adults and males (Hukkinen, Kaprio, Broms, Koskenvuo, & Korhonen, 2009). Similarly, socio-demographic data indicate that social smokers are less likely to be white compared to non-social smokers (Lisha et al., 2015; Villanti et al., 2017), which may be true for social ENDS user classes too. Research also has found that students in 2-year colleges have overall higher smoking rates compared to students enrolled in 4-year universities (Loukas, Murphy, & Gottlieb, 2008), and that very light smokers are more likely to be attending 4-year colleges compared to heavier smokers (Li, Loukas, & Perry, 2018). Thus, 4-year college students may be more likely to be social ENDS users and less likely to be non-social ENDS users. Lastly, compared to those who are daily “smokers,” those who are nondaily/light /“social smokers” (who used 1-10 cigarettes per day) are more likely to report using other tobacco products such as chewing tobacco, and dip/snuff in the past 30 days (Villanti et al., 2015). It is then possible that young adult social ENDS user classes are more likely than non-social ENDS user classes to also use other tobacco products such as hookah, cigars, and smokeless tobacco. In summary, based on research from low-volume and social smoking, it is possible that compared with the non-social ENDS user classes, the young adult social ENDS user classes are

younger in age, females, racial/ethnic minorities, 4-year college students, and current users of other tobacco products.

*Do ENDS use patterns predict subsequent ENDS use behaviors?*

Another key step in extending our understanding of ENDS use patterns is examining if ENDS use patterns predict subsequent ENDS use behaviors. That is, it is important to examine if certain classes of current ENDS users will continue to use ENDS or if they desist use, their prospective frequency of ENDS use over time, and their prospective ENDS nicotine dependence symptoms. Research indicates that there are transitions in smoking behaviors among light and intermittent young adult smokers (White, Bray, Fleming, & Catalano, 2009). There is also evidence of ENDS initiation and desistance among young adults (Agarwal, Loukas, & Perry, 2018; Creamer, Case, Loukas, Cooper, & Perry, 2019; Stanton et al., 2020), indicating that ENDS use may change over time among young adults. Existing evidence indicates that ENDS nicotine dependence is associated with increased use of ENDS among youth as well as adults (Morean, Krishnan-Sarin, & O'Malley, 2018; Vogel, Cho, McConnell, Barrington-Trimis, & Leventhal, 2020). Thus, it is possible that the classes of addicted ENDS users may continue to use ENDS over time, have subsequent ENDS nicotine dependence symptoms, and may possibly use ENDS more frequently than other classes. Conversely, non-addicted ENDS users may stop using ENDS over time, may be less likely to have subsequent ENDS nicotine dependence symptoms, or may use ENDS less frequently, compared to the addicted user classes, something research has yet to establish. Therefore, my dissertation also determined if the identified latent class membership of young adult current ENDS users predicted subsequent current ENDS use, frequency of ENDS use, and ENDS nicotine dependence symptoms one year later.

In summary, despite the increasing popularity of ENDS (McMillen, Gottlieb, Shaefer, Winickoff, & Klein, 2014; USDHHS, 2014), research is lacking on patterns of ENDS user classes. This dissertation aimed to determine 1) latent classes of young adult current ENDS users and common characteristics of young adults in these classes, and 2) if latent class membership predicted subsequent current ENDS use, frequency of ENDS use, and ENDS nicotine dependence symptoms one year later. Specifically, the first study of my dissertation identified current ENDS user classes and their common characteristics using Latent Class Analysis (LCA) among a cohort of young adult current ENDS users in Texas (see Figure 1). The second study of my dissertation used logistic and multiple regressions to examine if the latent class membership in Study 1 predicted subsequent current ENDS use, ENDS nicotine dependence symptoms, and frequency of ENDS use one year later. For Study 1, I examined six indicators of current ENDS user classes/subgroups, which were, self-identifying as a social ENDS user, frequency of ENDS use, ENDS nicotine dependence symptoms, binge alcohol use, marijuana use, and current cigarette use (see Figure 1, below). I also examined differences across the latent class memberships based on five covariates, including socio-demographics (age, sex, race/ethnicity, school type) and other current tobacco use [use of cigars, hookah, smokeless tobacco; (see Figure 1, below)]. For Study 2, I used three separate logistic and multiple regressions to determine if the identified latent class membership predicted current ENDS use, ENDS nicotine dependence symptoms, and frequency of ENDS use one year later, while controlling for the baseline covariates of socio-demographics (age, sex, race/ethnicity, school type) and other current tobacco use (use of cigars, hookah, smokeless tobacco). Thus, my dissertation sought to answer the following research questions:

Paper 1: Identified classes of current ENDS users including their common characteristics.

Research Question 1a: What are the distinct classes that emerge among current ENDS users?

There is limited evidence for the exact number of current ENDS user classes that may emerge. However, I hypothesized that at least four distinct classes of young adult current ENDS users will emerge based on the six indicator variables, which were, self-identifying as a social ENDS user, frequency of ENDS use, ENDS nicotine dependence symptoms, binge alcohol use, marijuana use, and current cigarette use. The four classes may include at least two distinct classes of social ENDS users: non-addicted and addicted social ENDS users and two distinct classes of non-social ENDS users: non-addicted and addicted non-social ENDS users. There may also emerge other current ENDS user classes in addition to the four hypothesized classes, which was explored in this dissertation.

Research Question 1b: How do the classes vary on socio-demographics and other tobacco use?

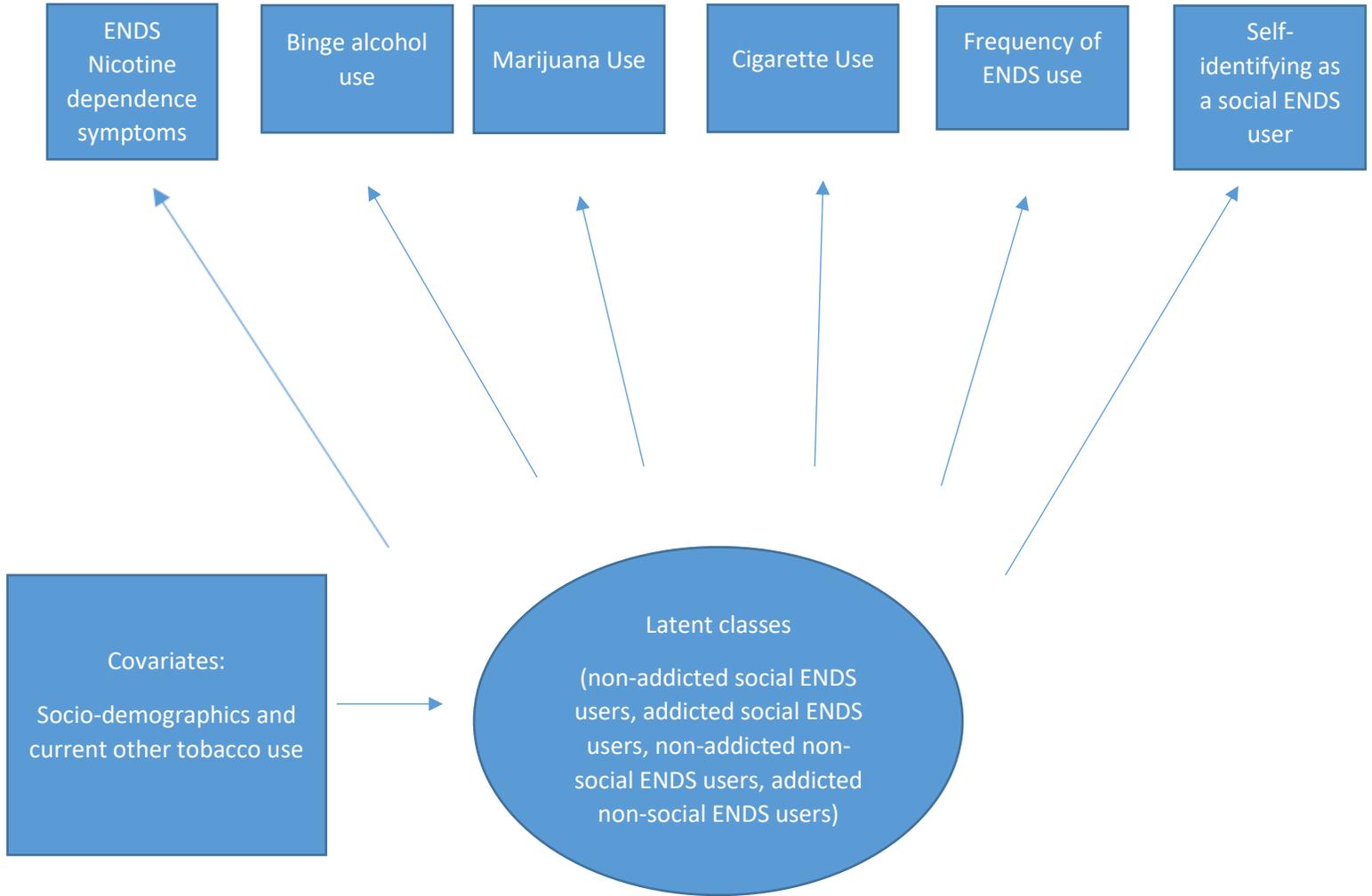
I hypothesized that the social ENDS user classes may be more likely to be younger in age, females, racial/ethnic minorities, 4-year college students, and be more likely to use other tobacco products such as hookah, cigars, and smokeless tobacco, compared to non-social ENDS user classes.

Paper 2: Determined if the latent class membership predicts subsequent current ENDS use, ENDS nicotine dependence symptoms, and frequency of ENDS use over a one-year period.

Research Question 2a: Does latent class membership predict subsequent current ENDS use, ENDS nicotine dependence symptoms, and frequency of ENDS use one year later?

I hypothesized that young adults within the addicted ENDS user classes will be more likely than their peers in the non-addicted classes to report current ENDS use, ENDS nicotine dependence symptoms, and higher frequency of ENDS use one year later, after controlling for baseline socio-demographics and current other tobacco use (use of cigars, hookah, smokeless tobacco).

*Figure 1.* Measurement Model Guiding Study 1.



## **Chapter 2: Literature Review**

### **Understanding patterns of Electronic Nicotine Delivery Systems use among young adults**

The existing research on young adult tobacco use falls into a few main categories of analysis: changing landscape and trends of tobacco use in recent years, health consequences of tobacco use patterns among young adults, young adults as a special group that warrants examination, and correlates and transitions of tobacco use behaviors in young adulthood. The following review of literature captures on the existing research young adult tobacco use followed by the rationale for the two studies in this dissertation. This dissertation aimed to determine 1) latent classes of young adult current ENDS users and common characteristics of young adults in these classes, and 2) if latent class membership predicted subsequent current ENDS use, frequency of ENDS use, and ENDS nicotine dependence symptoms one year later.

The tobacco landscape to which today's young adults are exposed goes beyond traditional cigarettes, smokeless tobacco, and cigars, to the growing band of alternative tobacco products that include hookah, snus, and Electronic Nicotine Delivery Systems (ENDS). Even though cigarettes are still the most used product by young adults with approximately 13.1% of 18-24 year old young adults reporting current cigarette use on the National Health Interview Survey (NHIS) in 2016 (Jamal et al., 2018), prevalence of cigarette smoking among all adults aged 18+ has been on a steady decline from 2005-2016 (20.9% to 15.5%) (Jamal et al., 2018). At the same time, there has been a steady increase in ever use of alternative tobacco products, including ENDS, among young adults aged 18-24 years (McMillen et al., 2014; USDHHS, 2014), even among those who never smoked cigarettes (Dai & Leventhal, 2019a). Results from the NHIS indicate a steady increase in the current use of ENDS among young adults aged 18-24 years. Whereas 5.1% of 18-24 year old young adults were currently using ENDS in 2014, the latest prevalence estimates from NHIS

indicate that 7.6% of 18-24 year old young adults were currently using ENDS in 2018 (Dai & Leventhal, 2019a). The data from the 2018 NHIS thus indicate a steep 46.2% increase in current ENDS use from 2017 to 2018 alone (Dai & Leventhal, 2019a).

Electronic Nicotine Delivery Systems, commonly known as electronic cigarettes were first marketed in the U.S in 2007, and since then ENDS are estimated to constitute \$3.5 billion business in the U.S, with \$125 million in ENDS advertising alone (USDHHS, 2016a). Electronic Nicotine Delivery Systems have evolved considerably since their introduction and there are a number of different types of ENDS products, such as the early-generation cigalikes to more recently evolved modifiable ENDS, and even more recently introduced vape pods (Barrington-Trimis et al., 2018; Huang et al., 2019). There is evidence that young adult populations are increasingly using later generation devices referred to as vape pods, pods, or pod mods (Fadus, Smith, & Squeglia, 2019). In fact, one of the later generation devices, JUUL, comprises 40% of the ENDS retail market share and \$150 million in retail sales in 2017 (Huang et al., 2019). Vape pods are sleek, USB-resembling devices that are customizable to individual preferences for flavors and nicotine content, and they promise effective nicotine delivery (Barrington-Trimis et al., 2018; Huang et al., 2019).

Regardless of the generation or type, ENDS contain cartridges generally filled with nicotine, flavor, and various other chemicals that are designed to emulate the visual, sensory, and behavioral aspects of smoking traditional cigarettes, but they do not contain tobacco (Etter & Bullen, 2011; Etter et al., 2013). Use of ENDS is concerning for several reasons, foremost of which is that these products contain nicotine that is addictive (Etter et al., 2013; Farsalinos et al., 2014; Rubinstein, Delucchi, Benowitz, & Ramo, 2018; USDHHS, 2016b, 2016c). Unfortunately, research indicates that some young adults may not even realize that ENDS contain nicotine and therefore not realize that ENDS are addictive (Amrock, Lee, & Weitzman, 2016; Gorukanti,

Delucchi, Ling, Fisher-Travis, & Halpern-Felsher, 2017). In fact, there is evidence that young adults lack knowledge about the nicotine content, especially in products such as JUUL (Boykan, Goniewicz, & Messina, 2019; Coleman et al., 2019; Goniewicz, Boykan, Messina, Eliscu, & Tolentino, 2019; McKelvey & Halpern-Felsher, 2020; Willett et al., 2019). Nicotine exposure is particularly problematic with newer generation vape pods because these contain high nicotine concentrations ranging from 21.8 mg/mL to 56.2mg/mL (Goniewicz et al., 2019), and consumption by young adults can alter brain development and result in subsequent disturbances in emotion and attention regulation (Yuan, Cross, Loughlin, & Leslie, 2015). Nicotine exposure during young adulthood can further condition developing young brains for addiction to other drugs, including methamphetamine and cocaine (USDHHS, 2016c).

Another cause for concern from ENDS use among young adults is co-occurring use with other tobacco products. A substantial portion of young adults who use ENDS also use other tobacco products specifically cigarettes (Loukas, Marti, & Perry, 2019). Research from the Marketing and Promotions Across Colleges in Texas (Project M-PACT) study (which will provide data for the current dissertation), found that young adults may in fact be using ENDS and cigarettes concomitantly and not necessarily using them for cigarette cessation (Case, Hinds, Creamer, Loukas, & Perry, 2020). Co-occurring use thus raises concerns of heightened nicotine consumption and delayed cessation. Indeed research on 17-24 year old young adults in California found that 22.1% report using ENDS as the first product they used, preceded only by the other most used first product, which are cigarettes [24.1%; (McKelvey & Halpern-Felsher, 2020)]. Thus, nicotine naïve young adults may experience nicotine addiction through ENDS and not other tobacco products. Nicotine use and dependence is specifically worrisome considering that young adulthood is a

period when life-long tobacco use is solidified (Ling & Glantz, 2002; USDHHS., 2012; White et al., 2009).

In addition to the risks from nicotine, use of ENDS is also concerning because they contain high levels of toxicants, including formaldehyde, acetaldehyde, and metals such as nickel, silver, tin, chromium, cadmium. Some of these toxicants are carcinogens associated with cancers and others are associated with increased risk for damage to the lungs and nasal cavity, as well as respiratory problems (Badea et al., 2018; Goniewicz et al., 2014; Hess et al., 2017; Khlystov & Samburova, 2016). However, as these products are relatively new, the long-term health consequences of using ENDS have not firmly been established (Etter et al., 2013; Farsalinos et al., 2014; Grana et al., 2014). Further, the regulations around ENDS products were passed in August 2016 (Abbasi, 2016) and are not yet fully implemented (Yu et al., 2018). Thus, there also continues to be concerns regarding variability in the constituents in ENDS products (Hawk & Maresso, 2019; Schroeder, 2018; Williams et al., 2018).

#### *Why are ENDS popular among young adults?*

There are variety of reasons that explain the steep increase in ENDS use among young adults despite the associated risks, including the likelihood of experimentation during this developmental period. Young adulthood or the period that starts at eighteen years until the mid-late twenties is characterized by transitions in various developmental domains (Arnett, 2014) including tobacco use (Orlando, Tucker, Ellickson, & Klein, 2004). Almost all tobacco use is initiated and regular tobacco use is established by the end of young adulthood (Breslau, Johnson, Hiripi, & Kessler, 2001; USDHHS., 2012). Research examining initiation of cigarettes and other alternative tobacco products, such as hookah, smokeless tobacco, snus, and ENDS indicates that 32% of 18-34 year old ever tobacco users reported tobacco initiation during young adulthood after

the age of 18 (Rath et al., 2012). Further 39% of tobacco users also reported progressing to regular tobacco use during this period (Rath et al., 2012). Research on cigarettes thus indicates that some young adults may still be developing smoking behaviors and may progress to heavier smoking during this developmental period (Biener & Albers, 2004). Young adults may also experiment with ENDS in this developmental period as there is evidence for both ENDS initiation and desistance of ENDS over time (Agarwal et al., 2018; Loukas et al., 2019; Stanton et al., 2020). Thus, it is possible that some young adults are experimenting with ENDS, but others may be moving to heavier ENDS use patterns (USDHHS., 2012; White et al., 2009) within this developmental period, which could partially explain the heightened prevalence of ENDS among young adults.

Another reason for heightened prevalence of ENDS use may be that young adults are the youngest legal targets of the tobacco industry, which has been directly marketing their products to this population for years (Ling & Glantz, 2002). Indeed tobacco industry documents have long recognized this developmental period as an opportunity to incorporate smoking in young adults' social life, given that young adults go through major life transitions and challenges such as moving to college, getting jobs, and changes in social behavior (Ling & Glantz, 2002). Evidence on ENDS marketing indicates that the ENDS industry utilizes multi-channel marketing for ENDS promotion that include social networking sites (Mackey, Miner, & Cuomo, 2015) such as Twitter and Instagram (Huang et al., 2019; Padon, Maloney, & Cappella, 2017). Marketing of ENDS has been focused on using positive feelings/imagery while featuring young adult peers and celebrities in product endorsements, which can develop young people's positive attitudes towards ENDS use (Padon et al., 2017). Moreover, marketing of these products often focuses on using ENDS in places where smoking may not be allowed, reduced harm from using ENDS compared to cigarettes, and

use of ENDS for cigarette cessation, which may add to their appeal to young adults (De Andrade, Hastings, & Angus, 2013). Young adults may also be likely to use ENDS because this population is open to experimenting with newly introduced, novel products (Johnston, O'Malley, Bachman, & Schulenberg, 2010) and this population finds ENDS products innovative (Trumbo & Harper, 2013).

#### *What we know about patterns of ENDS use*

Despite the harms associated with ENDS use, there is evidence that ENDS use is increasingly prevalent among young people and that young adults have the highest prevalence of use among all adults (Dai & Leventhal, 2019a; McMillen et al., 2014). However, we know little about patterns of ENDS use among young adults. Understanding ENDS use patterns, their characteristics, and their roles in subsequent ENDS behaviors is critical to developing tailored tobacco control strategies and messaging for different classes of users.

Limited longitudinal research tracking changes in ENDS use indicates that young adults' use of ENDS is not stable; that there appear new users of ENDS during young adulthood, but also that ENDS use desists or declines during this developmental period (Agarwal et al., 2018; Stanton et al., 2020). For instance, longitudinal data from Project M-PACT indicates that about 16% of young adults aged 18-29 years who had never tried ENDS at baseline initiated ENDS use within a one-year period (Agarwal et al., 2018). Additional data from Project M-PACT indicate that current use of ENDS declines with age during young adulthood (Loukas et al., 2019). Similarly, data from the Population Assessment of Tobacco and Health (PATH) study show that 18-24 year old young adults are unlikely to continue using ENDS after two years (Stanton et al., 2020). These differences in long-term ENDS use patterns may be partially attributed to the frequency of use in the past 30 days. For instance, data from the Minnesota Adult Tobacco Survey (MATS) examining

past 30-day ENDS use among adults aged 18 years and older who were current smokers or recently quit cigarettes at baseline found that, daily ENDS use at baseline was associated with subsequent past 30-day use one year later. The study also found that infrequent use at baseline (up to 5 days in the past 30 days) was associated with not reporting past 30-day ENDS use subsequently after one year (Amato, Boyle, & Levy, 2017). Data from the MATS are particularly important for advancing our understanding of ENDS use among adults in that they indicate that those who use ENDS heavily may be likely to continue using ENDS over time, whereas those who are less frequent users may desist use, which has not been explored in existing research yet. Further, these data also cannot provide information specific to young adults' ENDS use and they provide limited information about the subset of adults that are non-daily ENDS users.

Ample evidence indicates that even non-daily tobacco use can increase risk for nicotine dependence (DiFranza et al., 2007; DiFranza et al., 2002; Panday, Reddy, Ruiter, Bergström, & de Vries, 2007) and that young adults who are not daily tobacco users may continue to use tobacco (Johnson et al., 2019; White et al., 2009). Thus, non-daily users may progress to regular tobacco use or they may desist use across time. Unfortunately, few studies examine the heterogeneity within ENDS users. Thus, we know little about patterns of ENDS use and long-term consequences of these patterns. Additional research is needed to understand nuanced patterns of ENDS use and determine factors associated with these patterns, particularly during young adulthood, the period when lifelong use is established (Biener & Albers, 2004; Breslau et al., 2001; USDHHS., 2012).

#### *What we can draw from existing research base on cigarette use among young adults*

To begin to understand patterns of ENDS use and their consequences among young adults, we can infer from the sizeable literature base examining cigarette use patterns. In particular, a key change in the tobacco use behaviors of 18-29 year old young adults is the shift towards “low-

volume” smoking patterns (Schane et al., 2009a). Low-volume smoking covers a wide gamut of low consumption patterns of smoking behaviors. Although different studies have different definitions for these patterns, all studies typically use two metrics, which are, consumption of cigarettes per day and non-daily smoking. For instance, non-daily smoking and at the rate of fewer than 5 cigarettes per day was defined as “chipping” in an early research study conducted in the 80s (Shiffman, 1989). Low-volume smoking has also been conceptualized as non-daily or occasional cigarette smoking or smoking on some days but not every day (Schane et al., 2009a), but can also include intermittent or light smoking and very light smoking [usually defined as 5 or fewer cigarettes per day; (Li et al., 2015; Pierce et al., 2009)]. Intermittent smoking has also been defined as smoking about 4 days per week, and about 4 cigarettes per day on smoking days (Shiffman, Ferguson, Dunbar, & Scholl, 2012). Despite the varying definitions, there is consensus across studies that low-volume cigarette use behaviors are prevalent, with up to 88% of young adult smokers consuming five or fewer cigarettes per day (Li et al., 2018; Pierce et al., 2009).

A very important, but distinct low-volume sub-pattern of smoking is social smoking or smoking primarily in social situations (Moran et al., 2004; Villanti et al., 2017). Estimates from various studies have found that 51%-80% of young adults report smoking only in social situations (Jiang et al., 2014; Lisha et al., 2015; Moran et al., 2004; Rath et al., 2012; Song & Ling, 2011), which makes social smoking a very widespread low-volume smoking behavior. Like low-volume smoking overall, researchers use various definitions for social smoking. One of the earlier studies on students from 120 4-year U.S. colleges participating in the Harvard School of Public Health College Alcohol Study (CAS), conceptualized social smokers as those who smoked mainly with other people rather than alone (Moran et al., 2004). Other studies on young adults defined social smokers as non-daily smokers who smoke exclusively in social situations often when drinking

alcohol (Berg et al., 2012; Hoek et al., 2013). Like low-volume cigarette users, social smokers may not be fully aware of the health consequences of even occasional tobacco use and they may not even identify themselves as smokers (Berg et al., 2010; Hoek et al., 2013; Levinson et al., 2007; Ridner et al., 2010; Schane, Glantz, & Ling, 2009b), which in turn may make them less susceptible to tobacco control efforts.

There are other public health concerns with low-volume smoking among young adults. First, low-volume smokers may not identify as smokers and therefore sabotage tobacco control efforts. Specifically, there is evidence from the Nicotine Dependence in Teens (NDIT) study, that non-daily low-consumption smokers aged between 22 and 28 years were less likely to give importance to long-term health concerns associated with smoking (Wellman et al., 2018), thereby sabotaging tobacco control efforts and even delaying cessation. Second, low-volume smoking in itself is a public health concern since research has suggested that symptoms of nicotine dependence (such as loss of autonomy) can be experienced after even a very low level of cigarette consumption such as less than 2 cigarettes per day (DiFranza et al., 2007). Third, low-volume smokers may also progress to heavier smoking behaviors. For instance, one study on adolescents and young adults found that light and intermittent smoking is less stable than non-smoking and heavy smoking over a two-year period, and that young adults who are light and intermittent smokers are as likely to transition to heavier smoking patterns compared to transitioning to non-smoking patterns over time (White et al., 2009). Similarly, evidence from another study on smokers aged 24 years and older found that only 36.4% of low-rate smokers who smoked less than 5 cigarettes per day maintained low-rate smoking. Among the remaining, 5.5% of low-rate smokers (defined as fewer than 5 cigarettes per day) became occasional smokers (did not smoke daily in the past 30 days), 20.8% of low-rate smokers increased their consumption to become regular smokers (smoked more than

five cigarettes a day), over a period of 20 months (Zhu, Sun, Hawkins, Pierce, & Cummins, 2003). Another study on adults found that majority of adults who were light smokers (smoked less than five cigarettes a day) transitioned to non-smoking, moderate smoking (5-19 cigarettes per day), or even heavy smoking (at least 20 cigarettes per day) over a 6 year period (Hukkinen et al., 2009). Results from the Truth Initiative Cohort study also indicate that young adults aged 18-35 years who identified themselves as social smokers did not stop smoking during young adulthood over a 5 year period (Johnson et al., 2019), thus implying that even social smokers may be sustaining smoking habits and not quitting smoking. In summary, low-volume smoking including social smoking among young adults may result in sustained or even increased use of tobacco over time and delayed cessation, which ultimately sabotage tobacco control efforts.

#### *Low-volume ENDS use and gaps in existing research*

Given the shift towards low-volume and social smoking patterns among young adults, there is a possibility that low-volume ENDS use is also gaining popularity among young adults. Most studies on ENDS examine dichotomous indicators of ENDS use/non-use and past 30-day ENDS use (Coleman et al., 2017; Harrell et al., 2017; King, Patel, Nguyen, & Dube, 2014; Ramo, Young-Wolff, & Prochaska, 2015), or daily v/s non-daily use (Levy, Yuan, Li, Mays, & Sanchez-Romero, 2019), often ignoring the volume and changes in patterns of ENDS used. Research has just begun to categorize ENDS users based on their use frequency in the past month (Amato et al., 2016). Using data from the 2014 MATS, Amato et al. (2016) categorized participants who used ENDS less than or equal to 5 days in the past 30 days as ‘infrequent’ users, those who used ENDS on all 30 days as ‘daily’ users, and those who used ENDS between 6 and 29 days as ‘intermediate’ users (Amato et al., 2016). Evidence indicates that 59% of adults aged 18 years and older report infrequent ENDS use, defined as use of ENDS up to 5 days in the past 30 days, while only 28.7%

indicate intermediate ENDS use, defined as use of ENDS 6-29 days in the past 30 days and 12.3% report daily use (Amato et al., 2016). Evidence from other research indicates that 50% of all 25+ year old current ENDS users tend also to be low-volume users, who use ENDS for 1-4 days in the past 30 days (Pulvers et al., 2015). Still other research from the PATH study indicate that among adult (18+ years) past 30-day ENDS users, 42.2% report infrequent use of ENDS conceptualized as use on ‘some days’ and use on 0–2 days in the past 30 days, 36.5% report moderate ENDS use conceptualized as use on ‘some days’ and use on >2 of the past 30 days, and only 21.3% report daily ENDS use in the past 30 days (Coleman et al., 2017). Taken together, evidence indicates that most of today’s adult current ENDS users (including young adult users) tend to be non-daily, low-volume ENDS users as well. However, the existing research is still descriptive and we do not know about the characteristics of young adult low-volume current ENDS users, and whether a portion of them are social ENDS users, a class which cigarette research has found to be distinct from other smokers (Villanti et al., 2017).

### *ENDS use as a social behavior*

There is evidence that young adults believe ENDS use can have a positive social impact (Wallace & Roche, 2018) and that ENDS can play a role in positive social enhancement. That is, young adults perceive that these products facilitate social respect, popularity, liking by peers, as well as help people enjoy social interactions more (Hendricks & Brandon, 2008; Piñeiro et al., 2016; Pokhrel et al., 2014). It is possible then that some of today’s young adult ENDS users in addition to being low-volume users, may also be social ENDS users, a sub-group who like social smokers, potentially use ENDS exclusively in social contexts (Shiffman et al., 2015). According to the Social Cognitive Theory (SCT), individuals’ social environments present opportunities to communicate with others and observe their behaviors and their consequences, which can foster

learning of other's behaviors (Glanz, Rimer, & Viswanath, 2008). From this perspective, ENDS use, particularly social ENDS use, can be established during interactions among young adults' peers and those individuals with whom young adults live. In fact, research indicates that peer and family ENDS use is positively associated with adolescents' ENDS use (Barrington-Trimis et al., 2015). Research further indicates that college students' initiation and use of tobacco is indeed influenced by their peers and family (Kong, Morean, Cavallo, Camenga, Krishnan-Sarin, et al., 2014; Richter, Caraballo, Pederson, & Gupta, 2008). Further, there is evidence that use of ENDS is increasing among young adults who frequent bars and who do not smoke cigarettes (Kalkhoran, Padilla, Neilands, & Ling, 2016), indicating that nicotine naïve young adults may view ENDS as a social facilitator. However, research has yet to examine ENDS use patterns among young adults. Thus, the purpose of this dissertation was to 1) identify classes of current ENDS users as well as to determine common characteristics of these classes, and 2) determine if class membership predicted subsequent current ENDS use, ENDS nicotine dependence symptoms, and frequency of ENDS use one year later.

#### *How do we assess social ENDS use?*

When assessing social ENDS use as a potential class of today's young adult ENDS users, we cannot simply ask young adults to self-identify as social ENDS users since solely assessing self-identification criterion alone may not accurately capture the behavior. For example, results from one study found that only about 43% of 18-25 year old young adults who identify themselves as social smokers also behaved as such, that is they smoked mainly or only with others (Song & Ling, 2011). Results from another cross-sectional study indicate that only about a quarter (27%) of 18-25 year old young adults who identify themselves as social smokers actually behave as social smokers as well; that is, they also smoked cigarettes mainly or only with others, compared to 50%

of young adults in the study sample who identify themselves as social smokers but did not use cigarettes mainly or only in the company of others (Lisha et al., 2015). Yet other research among young adults has found that more than half (57%) of social smokers self-identified as social or occasional smokers and 66% of social smokers indicated smoking mainly or only with others, and that self-identification was the primary indicator that differentiated the class of social smokers from other smokers and non-smokers (Villanti et al., 2017). Thus, self-identification as a social ENDS user in the presence of others is important to assess, but must be assessed along with other factors that may together capture young adults' ENDS use.

Research on cigarette smoking provides evidence for some other factors, in addition to self-identification, that may capture patterns of ENDS use; these are: frequency of ENDS use, ENDS nicotine dependence symptoms, binge alcohol use, marijuana use, and current cigarette use. For instance, young adult social smokers that tend to smoke fewer cigarettes per day or less than half a pack of cigarettes per day (Lisha et al., 2015; Moran et al., 2004), tend to be non-daily and light smokers, and less dependent on nicotine (Moran et al., 2004). Thus it may also be possible that social ENDS users may use ENDS infrequently; that is, up to 5 days in the past 30 days (Amato et al., 2016; Coleman et al., 2019; Pulvers et al., 2015) and are not dependent on nicotine compared to non-social ENDS users given their lower volume of ENDS used.

Examination of use of other substances such as alcohol and marijuana is also important for capturing varying patterns of ENDS use. We can draw upon Problem Behavior Theory (PBT) to understand the co-use behavioral covariates. According to PBT, progression to a certain pattern of regular ENDS use can be a part of the constellation of “problem behaviors,” in which young adults who use one class of substance, have increased likelihood of use of other classes of substances (Jessor, 1987; Jessor & Jessor, 1977). In agreement with PBT, research has highlighted the

comorbidity of risky behaviors such as alcohol, marijuana, and other tobacco use among social smokers, who tend to use cigarettes in social situations and contexts, such as when others are smoking and drinking alcohol (Shiffman et al., 2015; Villanti et al., 2017). In fact, social smokers are more likely than non-social smokers to use multiple substances together such as cigarettes, alcohol, and marijuana (Lisha et al., 2015; Villanti et al., 2017). Social smoking has been associated with binge drinking among young adults aged 18-25 years (Gubner, Delucchi, & Ramo, 2016), and studies generally find a positive association between social smoking and alcohol use (Hoek et al., 2013; Jiang et al., 2014). Similarly, compared to daily “smokers,” nondaily/light /“social smokers” (who used 1-10 cigarettes per day) are more likely to report using other tobacco products such as ENDS, chewing tobacco, and dip/snuff in the past 30 days (Villanti et al., 2015). Thus, based on theory and evidence from existing research, it is also possible that there are two broad classes of current ENDS users; social ENDS users and non-social ENDS users. Social ENDS users may have a high probability of reporting binge alcohol use, marijuana use, and reporting current cigarette use, compared to non-social ENDS users who may have a low probability of reporting binge alcohol use, marijuana use, and reporting current cigarette use. Taken together, in order to differentiate characteristics of classes of ENDS users, research may need to examine young adults’ 1) self-identifying as a social ENDS user, 2) frequency of ENDS use, 3) ENDS nicotine dependence symptoms, 4) binge alcohol use, 5) marijuana use, and 6) current cigarette use (see Figure 1).

#### *Heterogeneity among social and non-social ENDS users*

Identifying social ENDS user and non-social ENDS user classes is a first step in understanding ENDS use patterns. It is also important for research to examine potential heterogeneity within each of these two broader classes. We can once again draw upon the limited

existing research on cigarette use to understand this heterogeneity. Limited evidence indicates that there are a group of individuals who are social smokers and also identify and behave as light smokers, that is, they report on average less than 5 cigarettes per day, less than 5 days per week (Lisha et al., 2015). These individuals may still exhibit lower symptoms of nicotine dependence, compared to the other group of self-identified social smokers who identify as such but are not light smokers, that is they report on average using 10.22 cigarettes per day, on about 6.34 days per week, and higher nicotine dependence (Lisha et al., 2015). Thus, there is evidence that social smokers can vary in their intensity of cigarette use, that is number of cigarettes per day as well as use on the number of days in a week, and nicotine dependence. Thus, there could exist at least two distinct classes of social ENDS users both of whom have a high probability of self-identifying as a social ENDS user. However, addicted social ENDS users may have a high probability of using ENDS more frequently and also exhibiting ENDS nicotine dependence symptoms. Whereas non-addicted social ENDS users may have a high probability of reporting ENDS less frequently, and a low probability of reporting ENDS nicotine dependence symptoms. There may also exist at least two distinct classes of non-social ENDS users both of whom have a low probability of self-identifying as a social ENDS user. Addicted non-social ENDS users will have a high probability of using ENDS more frequently and a high probability of exhibiting ENDS nicotine dependence symptoms. Non-addicted non-social ENDS users in addition to having a low probability of self-identifying as a social ENDS user, may also have a high probability of using ENDS less frequently, and a low probability of exhibiting ENDS nicotine dependence symptoms.

Further, it is also possible that the two young adult social ENDS user classes additionally have a high probability of reporting binge alcohol use, marijuana use, and reporting current cigarette use compared to the two other young adult non-social ENDS user classes who will have

a low probability of reporting binge alcohol use, marijuana use, and reporting current cigarette use. It also seems logical to assume that like social smokers (Johnson et al., 2019), the classes of addicted ENDS users who have ENDS nicotine dependence symptoms may continue to use over time, whereas those classes that do not have ENDS nicotine dependence symptoms will stop using ENDS over time, something research has yet to establish clearly for even cigarettes among young adults (White et al., 2009). Understanding the nuances and various classes of ENDS users is important, as this information is useful in developing distinct tobacco control messages tailored to different classes of ENDS users.

*Covariates of ENDS use: Current other tobacco use and socio-demographics*

Another important step in understanding ENDS use patterns, is to identify covariates of various ENDS use classes, and how various ENDS use classes differ by those covariates. The heterogeneity in patterns of ENDS use behaviors among young adults can be explained by use of other tobacco products and socio-demographic factors. There is evidence that social smokers are more likely than non-social smokers to co-use cigarettes and other tobacco products such as hookah (Lisha et al., 2015; Villanti et al., 2017). Similarly, compared to daily “smokers,” nondaily/light /“social smokers” (who used 1-10 cigarettes per day) are more likely to report using other tobacco products such as ENDS, chewing tobacco, and dip/snuff in the past 30 days (Villanti et al., 2015). Thus, based on evidence from existing research on low-volume and social smoking, it is possible that young adult social ENDS users classes are more likely than non-social ENDS user classes to use other tobacco products such as hookah, cigars, and smokeless tobacco, something which is not clear from existing research but has been addressed in the present dissertation.

We also can draw upon existing research on low-volume smoking and social smoking to understand socio-demographic correlates of social ENDS use. Existing research has found that young adult low-volume smokers differ from heavier smokers with regard to age, sex, race/ethnicity, and type of college attended (4-year versus 2-year). One study on adults aged 18 years and older found that younger people (mean age 30) and females are more likely to report light smoking or smoking less than 5 cigarettes per day, compared to heavier smokers who smoked at least 20 cigarettes per day (Hukkinen et al., 2009), something which may also translate to ENDS use. Another recent study on young adults aged 18-24 years also found that social smokers are likely to be under the age of 21 (Villanti et al., 2017). Research has found that women in general are more likely to be low-volume smokers (Ackerson & Viswanath, 2009) and male smokers are generally unlikely to report light daily smoking or smoking 1-5 cigarettes per day (Trinidad et al., 2009). Further socio-demographic data indicate that social smokers are less likely to be white compared to non-social smokers (Lisha et al., 2015; Villanti et al., 2017), which may be true for social ENDS users too. Other research on adults aged 20-50 years also found that ethnic minorities are likely to report intermittent smoking and light daily smoking compared with whites (Trinidad et al., 2009). Further, research has found that students in 2-year colleges have overall higher smoking rates compared to students enrolled in 4-year universities (Loukas et al., 2008), and that very light smokers are more likely to be attending 4-year college compared to heavier smokers (Li et al., 2018). Thus, 4-year college students may be more likely to be social ENDS users and less likely to be non-social ENDS users. However, research has currently not explored these socio-demographic covariates for classes of young adult ENDS users. Nonetheless, it is possible that social ENDS user classes may be more likely to be younger in age (18-24 years old), females, racial/ethnic minorities, 4-year college students, and to use other tobacco products such as hookah,

cigars and smokeless tobacco, compared to all the other non-social ENDS user classes, something this dissertation has examined.

*Does class membership predict prospective ENDS use behaviors?*

Another step to limit and intervene on young adults' long-term ENDS use is to understand if ENDS use patterns predict subsequent ENDS use behaviors. Evidence indicates that there is substantial experimentation with ENDS products during young adulthood (Agarwal et al., 2018; Stanton et al., 2020). That is, initiation and desistence of ENDS occur during young adulthood, indicating that there are various patterns that need to be examined. Research to date has also not examined if ENDS use patterns predict subsequent ENDS use behaviors. However, we can again draw upon research examining trajectories of low-volume and social smoking, which suggest that some patterns of ENDS, such as social ENDS use, could stay stable or desist over time (Caldeira et al., 2012; Schane et al., 2009b; White et al., 2009).

There is evidence from tobacco industry documents that social smoking can remain a stable form of tobacco use among young adults (Schane et al., 2009b). Moreover, empirical evidence with young adults just entering college from high school indicates that the probability of light and intermittent smokers maintaining stable use across a 2-year period ranges from 56% to 72% (White et al., 2009). Findings from the College Life Study, a prospective study of incoming college students aged 17-19 years attending a large mid-Atlantic university, also found that 16% of the sample who were low-smokers (defined as smoking 1-3 days in the past 30 days) maintained their low-smoking throughout college (Caldeira et al., 2012), suggesting that low-volume smoking can stay stable over a period of time.

However, other evidence demonstrates that the stability of light and intermittent smoking is lower (56%-72%) compared to the stability of non-smoking (89%–91%) and heavy smoking (75%–90%) over time (White et al., 2009). Thus, other studies find that only a very small proportion of light (non-daily smokers) and low-volume smokers (defined as fewer than 5 cigarettes per day) report stable consumption over time (Hukkinen et al., 2009; Zhu et al., 2003). Hukkinen et al. (2009) found that only about 6% of 18 years and older light smokers who smoked less than 5 cigarettes per day continued their smoking pattern over a period of 15 years, while 39% reported quitting smoking, and 25% escalated to moderate or heavy smoking. Similarly, Zhu et al. (2003) found that among adults aged 24 years and older who smoked for at least 5 years, only 36% of low-rate smokers who smoked less than 5 cigarettes per day maintained their smoking pattern 20 months later, while 21% escalated to smoking more cigarettes compared to smoking at baseline (Zhu et al., 2003). The College Life Study also found that 8.3% of the sample who were low-smokers smoking 1-3 days in the past 30 days also reported smoking more frequently over time (Caldeira et al., 2012).

While there is evidence in support of stable cigarette use, there is also evidence for desistance among a good portion of young adults; for instance, previous research with women smokers aged 18-23 years found that most non-daily smokers quit smoking (about 55%) from their baseline non-daily smoking pattern after 7 years (McDermott, Dobson, & Owen, 2007). Later research also found similar transitions in that light and intermittent smokers (defined as consumption of up to 5 cigarettes per day), also transition to non-use over time (White et al., 2009). Thus, there is evidence for stability and desistance among young adult low-volume smokers, but we do not know about similar transitions among young adult ENDS user classes.

Emerging evidence indicates that there exist transitions and desistance in young adults' use of ENDS as well. For instance, 60% of 18+ year olds in the PATH study who indicated ENDS use at baseline were unlikely to continue using ENDS over a 2-year period (Stanton et al., 2020). Based on evidence from research on cigarettes, desistance is possible for some classes of ENDS users, particularly those that do not show nicotine dependence symptoms (Morean et al., 2018; Vogel, Cho, et al., 2020). Further, given that social smokers believe that they are less susceptible to health risks of smoking and to cessation messaging (Brown, Carpenter, & Sutfin, 2011; Schane et al., 2009b), the classes of addicted ENDS users may especially continue to use ENDS, also because they may have a high probability of demonstrating ENDS nicotine dependence. Alternatively, those non-addicted ENDS user classes who use ENDS less frequently and are less dependent on nicotine, may be likely to mature out of ENDS use as they get older (Coleman et al., 2019; Morean et al., 2018; Vogel, Cho, et al., 2020).

In summary, despite the increasing popularity of ENDS (McMillen et al., 2014; USDHHS, 2014), we know little about the patterns of ENDS use among young adults. To fill the gaps in the existing research, the purpose of this dissertation was to determine 1) latent classes of young adult current ENDS users and common characteristics of young adults in these classes, and 2) if latent class membership predicted subsequent current ENDS use, frequency of ENDS use, and ENDS nicotine dependence symptoms one year later.

### **Chapter 3: Methods**

Studies 1 and 2 of this dissertation utilized Latent Class Analysis (LCA) and Logistic and Multiple Regression analyses respectively, to understand the classes of current ENDS users and their subsequent ENDS use patterns one year later, among young adults aged 19-31 years. Study 1 used data from 463 participants from wave 4 (April-May 2016) of the Project M-PACT study to understand classes of current ENDS use. Study 2 used wave 4 (April-May 2016) and wave 6 (April-May 2017) data from 424 participants (who were included in Study 1) to examine if the latent class membership among current ENDS users predicted subsequent ENDS use behaviors one year later. Study 1 LCA used six indicator variables all assessed at wave 4, which were, self-identifying as a social ENDS user, frequency of ENDS use, ENDS nicotine dependence symptoms, binge alcohol use, marijuana use, and cigarette use, to discern classes of ENDS users. The ENDS use classes/sub-groups identified in Study 1 LCA then formed the preliminary basis for the Study 2 regressions to examine if the latent class membership at wave 4 predicted subsequent current ENDS use, ENDS nicotine dependence symptoms, and frequency of ENDS use at wave 6, which is one year later.

#### ***Participants***

Participants for this dissertation were 463 students for Study 1 and 424 students for Study 2 (that participated in Study 1), drawn from a larger cohort of 5,482 students who participated in Marketing and Promotions Across Colleges in Texas Project (Project M-PACT). Project M-PACT is a rapid response surveillance study that collected data for 8 waves, every six months beginning Fall 2014 to Spring 2017 and two yearly collections in Spring 2018 and Spring 2019. Participants were recruited in Fall 2014/Spring 2015 from one of 24 2-year and 4-year colleges in Texas. There were two eligibility criteria to participate in Project M-PACT- 1)

participants had to be part-time or full-time students enrolled in a program in a 4-year college or a vocational/technical program at a 2-year college, and 2) participants had to be 18-26 years old if they indicated lifetime non-use of tobacco or 18-29 years old if they indicated lifetime tobacco use, at wave 1. Lifetime tobacco use was defined by having ever smoked at least 100 cigarettes, or at least 20 cigars, or having ever used smokeless/spit/chewing tobacco at least 20 times. Given that Project M-PACT's aim was to examine transitions in tobacco use and there is evidence from research that most tobacco is initiated by the age of 26 (USDHHS., 2012), lifetime non-tobacco users over the age of 26 were excluded from participation.

#### *Dissertation sample*

For the purposes of this dissertation, data were drawn from waves 4 and 6 of Project M-PACT. Wave 4 data were collected in April-May 2016, and wave 6 data were collected one year later in April-May 2017. Data were drawn from wave 4 because participants were asked about self-identifying as a social ENDS user, one of the important indicators for the LCA analyses, for the first time in the M-PACT study at this wave. Only participants who reported ENDS use in the past 30 days at wave 4 were then assessed on self-identifying as a social ENDS user. Subsequently, waves 4 and 6 data were used for the regression analyses to examine if the latent class membership predicted subsequent current ENDS use, ENDS nicotine dependence symptoms, and frequency of ENDS use at wave 6. Note that a total of 480 participants self-identified as past 30-day ENDS users at wave 4. However, 17 participants had incomplete data on the five covariates and thus were dropped from analyses in Study 1 because in order to conduct the LCA analysis successfully complete data is required for the covariates (Nylund-Gibson & Hart, 2014). The remaining 463 participants that comprised the Study 1 sample make up 10.41% of the total participants in wave 4 for Project M-PACT (N=4448). For Study 2, an additional 39 students who were missing data

on past 30-day ENDS use at wave 6 were dropped from the regression analyses, leaving the sample for Study 2 regressions to be 424 participants, which make up 9.67% of the total participants in wave 6 for Project M-PACT (N=4384).

### ***Procedures***

The 24 colleges from which the young adult cohort was drawn for Project M-PACT were located in the five counties including the four largest metropolitan areas in Texas, which are, Austin, Dallas/ Fort Worth, Houston, and San Antonio. For Project M-PACT, only colleges with a minimum enrollment of 2,500 students were considered for inclusion. 2-year colleges were required to also have student enrollment in vocational/workforce programs. Initially, a total of 65 colleges were identified in the four target cities, out of which 37 were 2-year colleges with vocational programs and 28 were 4-year colleges. Three colleges of each type (2-year and 4-year) were selected from each metropolitan area, which made it a total of six colleges per metropolitan area in Texas. Thus, participants were drawn from a total of 24 colleges from the four areas that included 12 2-year colleges with vocational programs and 12 4-year colleges. All 2-year colleges and nine 4-year colleges were public institutions. The undergraduate enrollment for the 24 colleges ranged from 2,521 to 51,312 students in Fall 2014 for baseline data collection for Project M-PACT.

Students enrolled in the 24 colleges who met the eligibility criteria were recruited to participate in the online survey via email invitation. For 15 colleges, open records requests were submitted for undergraduate students' email addresses, and once the information was obtained, the project personnel sent students an invitation email via a secure server. Those students from 15 colleges who were emailed directly by project personnel received an introductory email invitation in addition to two follow up email reminders, the first reminder 5 days after the initial invitation, and the second reminder 6 days following the first reminder (11 days after the initial invitation).

The remaining nine colleges sent eligible students an invitation email through their own internal communication department, rather than project personnel contacting students directly. The students from the nine colleges who received emails through their respective colleges received at least one initial invitation email, and students from three of those nine colleges received one additional reminder email as well. The initial email invitation described the purpose of the study and included a link to an eligibility survey. The eligibility survey confirmed potential participants' student status as degree/certificate seeking, and contained questions on lifetime use of tobacco (i.e., lifetime cigarette, smokeless, and chewing tobacco) and age.

Eligible students who wished to participate in the study provided informed consent and then completed the online survey. More than 13,000 students ( $n=13,714$ ) were eligible to participate in the study and of these, 5,482 students (40%) provided consent and completed the baseline survey in Fall 2014/Spring 2015. Upon completion of the survey, each student received an e-gift card incentive. At waves 4 and 6, from which data were drawn for this dissertation, students received a \$20 e-gift card. Further, all students were entered into a drawing to win one of twenty \$50 e-gift cards at all waves. Response rates for waves 4 and 6 were 81% ( $n=4448$ ) and 80% ( $n=4384$ ) of the larger M-PACT cohort ( $n=5482$ ) at wave 1, respectively.

### ***Human Subjects Considerations***

Project M-PACT was reviewed and approved by the University of Texas at Austin Institutional Review Board (2013-06-0034).

## *Measures*

Measures for the current study were adapted from existing surveys and were reviewed by several tobacco control experts who provided feedback on survey revisions. Final survey modifications were also conducted through a process of cognitive interviewing with 25 young adults who did not participate in Project M-PACT (Hinds III et al., 2016).

### *LCA indicator variables that were used for formation of latent classes for studies 1 & 2*

As shown below in Table 1, there were 6 indicator variables in the LCA model for Study 1, that were also used for forming the classes for the regression analyses in Study 2. All the indicator variables were assessed at wave 4 and re-coded in dichotomous variables (0/1), given that the LCA model requires the indicator variables to be dichotomous (Nylund-Gibson & Hart, 2014). The latent class classification dummy variable then formed the independent variable for the regression analyses in the current study. Three separate regressions then predicted three separate outcomes for at wave 6 for Study 2, which were, current ENDS use at wave 6 (tested with a logistic regression), ENDS nicotine dependence symptoms at wave 6 (tested with a logistic regression), and frequency of ENDS use at wave 6 (tested with a multiple regression). Socio-demographics of sex, age, race/ethnicity, and college type, and wave 4 past 30-day use of other tobacco products (i.e., cigars, hookah, and smokeless tobacco use) were all included as covariates in the regression models simultaneously.

Table 1: Six Indicators of the LCA and for forming the classes for regression analyses

Item	Description
1	Self-Identifying as a social ENDS user – <i>used ENDS products when with friends or in a social situation</i>
2	Frequency of ENDS use – used ENDS on the 0-30 days in the past 30 days
3	ENDS nicotine dependence symptoms – <i>felt like really needing to use ENDS, had a strong craving for ENDS, used ENDS within 30 minutes of waking</i>
4	Binge alcohol use- <i>five or more drinks of alcohol in a row in the past 14 days</i>
5	Marijuana use- <i>used marijuana in the past 30 days</i>
6	Current cigarette use- <i>used cigarettes in the past 30 days</i>

#### *Self-identifying as a social ENDS user*

Self-identifying as a social ENDS user was assessed at wave 4 with one item developed for project M-PACT, “Do you only use ENDS products (i.e. e cigarettes, vape pens, e-hookah, or mods) as intended (i.e. with nicotine e liquid/e juice) when you are with your friends or in a social situation?” Responses were coded as 0=yes (social ENDS user), 1=no (non social ENDS user).

#### *Current ENDS use and Frequency of ENDS use*

Frequency of ENDS use or past 30-day ENDS use was assessed at wave 4 for the LCA in Study 1 and again at wave 6 as one of the outcome variables in Study 2, using an item adapted from the Youth Tobacco Survey [YTS; (Starr, Rogers, Schooley, Perter, & Wiesen, 2005)] and the PATH study (Coleman et al., 2017). The current ENDS use item included a description of the range of products under ENDS, including a picture of various ENDS products, followed by asking, “How many of the past 30 days have you used any ENDS product (i.e. an e-cigarette, vape pen, e-hookah, JUUL/pod vape, or mod), even one or two puffs, as intended (i.e. with nicotine cartridges/pods and/or e-liquid/e-juice)?” Using categories defined in existing research (Amato et

al., 2016), participants who indicated using ENDS less than or equal to 5 days in the past 30 days, were categorized as infrequent ENDS users and coded as 0. Participants who reported using ENDS from 6-30 days in the past 30 days (intermediate and daily users) were combined together as regular ENDS users and coded as 1 (Amato et al., 2016).

### *ENDS nicotine dependence symptoms*

ENDS nicotine dependence symptoms was assessed at wave 4 for the LCA in Study 1 and again at wave 6 as one of the outcome variables in Study 2 using three items. Two items were adapted from DiFranza and colleagues (2002) and one other item was adapted from Heatherton and colleagues (1991) respectively (DiFranza et al., 2002; Heatherton, Kozlowski, Frecker, & FAGERSTROM, 1991). The first two items asked ever ENDS users “Have you ever felt like you really needed to use an ENDS product?” (0=no and 1=yes), “Have you ever had a strong craving for an ENDS product?” (0=no and 1=yes) (DiFranza et al., 2002). Additionally past 30 day ENDS users were asked, “How soon after you wake up do you typically use your first ENDS product?” (Heatherton et al., 1991). For the last item, response options included “within 5 minutes of waking,” “6-30 minutes after waking,” “31-60 minutes after waking,” “61 or more minutes after waking,” and “I am not a daily cigarette smoker.” Consistent with other studies (Loukas et al., 2016), for the purposes of the this dissertation, the last item was re-coded into a dichotomous variable for the LCA (Nylund-Gibson & Hart, 2014) so that only participants who smoked their first ENDS within 30 minutes of waking were coded “1” and all others were coded as “0,” including non-past 30 day ENDS users. Responses for the three items were summed and participants with no dependence symptoms were assigned a code of 0 and participants who reported at least one dependence symptoms were assigned a code of 1.

### *Binge alcohol*

Participants' binge alcohol use was assessed at wave 4 with a question adapted from the Monitoring the Future study [MTF; (Schulenberg et al., 2017)] that asked "During the past 14 days, on how many days did you have 5 or more drinks of alcohol in a row?" Answer options included "0 days," "1 or 2 days," "3 to 5 days," "6 to 9 days," and "10 to 14 days." Individuals who reported consuming five or more drinks in a row on one or more days were coded 1, while those who reported no binge alcohol consumption (0 days) were coded 0.

### *Marijuana use*

Current or past 30-day marijuana use was assessed at wave 4 using an item from the MTF study (Schulenberg et al., 2017), asking "During the past 30 days, how many occasions, or times, if any, have you used marijuana? (Other names for marijuana are pot and weed.)" Response choices included "0 times," "1-2 times," "3-5 times," "6-9 times," "10-19 times," "20-39 times," and "40 or more times." Individuals who reported using marijuana one or more times were coded 1, while those who reported no marijuana use (0 times) were coded 0.

### *Current cigarette use*

Current or past 30-day use of cigarettes was assessed at wave 4 with an item adapted from the PATH study (Coleman et al., 2017). The item asked "On how many days of the past 30 days did you smoke cigarettes?" Use of cigarettes in the past 30 days were scored 0=used on 0 days in the past 30 days or 1=used on 1 or more days in the past 30 days.

### *Five covariates for Study 1 LCA and Study 2 regression models*

Once the emerging classes were identified using the six indicator variables, Study 1 examined covariates of ENDS user classes to determine common characteristics of the young adults in these classes and how the classes varied based on five factors, including socio-demographics of sex, age, race/ethnicity, and college type, and wave 4 past-30 day use of other tobacco products (i.e., cigars, hookah, and smokeless tobacco use). These socio-demographics and wave 4 past 30-day use of other tobacco products were also included as covariates in the regression models simultaneously, for Study 2.

#### *Socio-demographic covariates*

Sex was assessed at wave 1 (0 = female, 1 = male); age was assessed at wave 4 and dichotomized [25 years and above=0 and 19-24 years=1; (Agarwal et al., 2018)]. Lastly, race/ethnicity, also assessed at wave 1, was dummy-coded with non-Hispanic white as the reference group (coded as 0) and other groups, Hispanic or Latino, black or African American, Asian, and all other race/ethnicity coded as 1 to facilitate comparison of each racial/ethnic minority group against non-Hispanic white participants. Type of college was also assessed at wave 1 [0 = 2-year college, 1 = 4-year college; (Cooper, Loukas, Case, Marti, & Perry, 2018; Loukas, Marti, Cooper, Pasch, & Perry, 2018)].

#### *Other tobacco use covariates*

Current or past 30-day use of other tobacco products was assessed at wave 4 with an item adapted from the YTS (Starr et al., 2005) and the PATH study (Coleman et al., 2017). The other products assessed included cigars, hookah, and smokeless tobacco. The item asked “On how many days of the past 30 days did you smoke/use [product]?” Use of each tobacco product was

scored 0=used on 0 days in the past 30 days or 1=used on 1 or more days in the past 30 days. The scores for all of the three products were summed so that the scores for current use of other tobacco products for each participants ranged from 0-3 (Agarwal et al., 2018).

### ***Data analysis for Study 1***

#### *Missing data for Study 1*

Based on the assumption that the missing data were missing at random or missing completely at random (Collins, 2010), I used a full-information maximum likelihood (FIML) approach so that existing missing data on the indicator variables were accounted for within the analysis model itself (Collins, 2010; Nylund-Gibson & Hart, 2014). However, as noted previously, this study had 480 eligible participants who were current ENDS users at wave 4. An additional 17 participants had incomplete data on the five covariates and thus were dropped from all analyses (Nylund-Gibson & Hart, 2014). Only two participants were missing data on the indicator variables; and thus, were retained in the analysis.

#### *Latent Class Analysis for Study 1*

I conducted LCA in Mplus 8 (Collins, 2010; Muthén & Muthén, 2018; Villanti et al., 2017) to address the aim for Study 1, which was, to identify classes of current ENDS users as well as to determine common characteristics of these classes, among a cohort of young adults in Texas. Latent Class Analysis is a technique that is commonly used to identify distinct classes of behaviors, such as alcohol and tobacco use (Rinker & Neighbors, 2015; Villanti et al., 2017). The benefit of using this person-centered approach is that it uses a variety of indicator variables to examine intersections and complexity of behaviors within a person (Lanza & Rhoades, 2013). This approach enabled me to explore heterogeneity among young adult current ENDS users based on

the set of pre-determined indicator variables (Nylund-Gibson & Hart, 2014). For this dissertation Study 1, LCA identified classes of current ENDS users by examining the intersection of of the six identified indicator variables i.e., self-identifying as a social ENDS user, frequency of ENDS use, ENDS nicotine dependence symptoms, binge alcohol use, marijuana use, and current cigarette use. I expected that the following classes could emerge at wave 4: non-addicted non-social ENDS users, addicted non-social ENDS users, non-addicted social ENDS users, and addicted social ENDS users.

To understand the LCA results and label the emerging classes, I examined the 1) conditional item-response probabilities and 2) class probabilities (Collins, 2010; Nylund-Gibson & Hart, 2014). Item-response probabilities were used to label the classes and understand the classes, as well as assess the participants' probability of responding to an item based on the class they belong to (Collins, 2010; Nylund-Gibson & Hart, 2014). The class probabilities assessed the relative size of the emerging classes or sub-groups (Collins, 2010; Nylund-Gibson & Hart, 2014), which helped me understand if an emerging ENDS class is widespread or rare.

#### *Assessing model fit and determining number of classes for Study 1*

One of the most important steps in LCA is to determine the number of classes. After conducting the LCA in Mplus 8 (Collins, 2010; Muthén & Muthén, 2018; Villanti et al., 2017), the best fitting model was selected by first running models with two to four classes and comparing each of the models on various fit indices as well as parsimony of interpretation. In selecting the best fitting model, absolute tests of model fit were considered, which included the Bayesian Information Criteria (BIC) and the Akaike Information Criterion (AIC), for both of which smaller values are ideal (Nylund-Gibson & Choi, 2018). I also took into account entropy that is a measure of classification quality and for which values as close to 1 as possible are considered ideal (Celeux

& Soromenho, 1996). Lastly, I also took into consideration the Vuong-Lo-Mendell-Rubin test (VLMR) and the Bootstrapped Likelihood Ratio Test (BLRT). When these two tests indicate a non-significant p-value, it points that the previous class is the better fitting model (Collins, 2010). Thus, in the best fitting model, the AIC and the BIC are the lowest among all the models, the entropy is the closest to 1, and the VLMR and BLRT statistics are significant (Celeux & Soromenho, 1996; Collins, 2010; Nylund-Gibson & Choi, 2018).

### *Examining the covariates in the LCA for Study 1*

Once I determined the best fitting and most parsimonious model, I added all the covariates to that model simultaneously to explore the characteristics of ENDS user classes and how the classes vary based on socio-demographics and current use of other tobacco products, including, use of cigars, hookah, and smokeless tobacco (Nylund-Gibson & Hart, 2014). I examined the associations between the covariates and the latent classes using the R3STEP command to run the multinomial logistic regression in M-PLUS 8 (Muthén & Muthén, 2018). The multinomial logistic regression is a comparison of the probability of being in a particular latent class compared with a chosen reference latent class (dependent variable), so that all the values of the covariates (independent variables) are compared with the reference class (Nylund-Gibson & Hart, 2014).

### *Data Analysis for Study 2*

#### *Missing data for Study 2*

Of the 463 participants in Study 1, 39 participants (8.4% of the sample for study 1) were missing data on the wave 6 past 30-day ENDS use outcome variable. The remaining 424 participants had complete data on the other two waves 6 outcomes, that is, ENDS nicotine

dependence symptoms and frequency of ENDS use. Thus, the sample for the Study 2 regression analyses was 424 participants.

### *Regression analyses for Study 2*

The LCA in Study 1 examined young adult current ENDS user classes at wave 4. Whereas the regression analyses in Study 2 were able to predict prospective changes in ENDS use behaviors from wave 4 to wave 6 (a one year period), based on the LCA class membership at wave 4. Therefore, for Study 2, I built on the results from the LCA in Study 1, and conducted three regression analyses to determine the role of of the identified class membership from Study 1 in subsequent 1) current ENDS use, 2) ENDS nicotine dependence symptoms, and 3) frequency of ENDS use one year later. Three separate regressions were run in SPSS version 26 to predict three separate outcomes at wave 6, which were, current ENDS use at wave 6 (tested with a logistic regression), ENDS nicotine dependence symptoms at wave 6 (tested with a logistic regression), and frequency of ENDS use at wave 6 (tested with a multiple regression). In all regression models, the latent class classification variable served as the independent variable and was dummy coded so that the highest risk class, that is, high-risk poly tobacco and substance users were the reference group. Socio-demographics of sex, age, race/ethnicity, and college type, and wave 4 past 30-day use of other tobacco products (i.e., cigars, hookah, and smokeless tobacco use) were all included as covariates in the regression models simultaneously. Further, frequency of ENDS use at wave 6 was log transformed as the outcome variable because it was non-normally distributed.

## Chapter 4: Study 1

### Characterizing young adult Electronic Nicotine Delivery System users

#### *Abstract*

*Introduction.* Despite the increasing popularity of Electronic Nicotine Delivery Systems (ENDS), research is lacking on patterns of young adult current (i.e., past 30-day) ENDS use. The aim of this study was to examine classes of young adult current ENDS users and determine common characteristics of these classes among a cohort of young adults in Texas. *Methods.* Participants were 463 young adults aged 19-31 years, who were drawn from wave 4 (April-May 2016) of the Marketing and Promotions across Colleges in Texas project (Project M-PACT), which collected data every 6 months beginning November 2014 to February 2015 from a larger cohort of college students across Texas. Latent Class Analysis with six indicator variables, which are, 1) self-identifying as a social ENDS user, 2) frequency of ENDS use, 3) ENDS nicotine dependence symptoms, 4) binge alcohol use, 5) marijuana use, and 6) current cigarette use, was used to discern classes of young adult current ENDS users. Other tobacco use and socio-demographics were examined as covariates contributing to the membership within various ENDS user classes. *Results.* Findings identified three distinct classes of users, including non-nicotine dependent social ENDS users, high-risk poly-tobacco and substance users, and nicotine dependent ENDS users. *Implications.* Results underscore the heterogeneity among young adult current ENDS users and the need for development of distinct tobacco control messaging and intervention strategies tailored to different sub-groups of young adult ENDS users.

## ***Introduction***

There has been a steady increase in the use of Electronic Nicotine Delivery Systems (ENDS) from 2014-2018 among young adults, who report the highest prevalence of use among all adults (Dai & Leventhal, 2019a; Kasza et al., 2017). Approximately 8% of 18-24 year old young adults were currently using ENDS in 2018 (Dai & Leventhal, 2019a). Despite the increasing popularity of ENDS and the health concerns associated with their use, including nicotine dependence (Dai & Leventhal, 2019a; Etter et al., 2013; Farsalinos et al., 2014; Kasza et al., 2017), little is known about patterns of ENDS use among young adults. To fill the gaps in existing research, this study identified classes of current ENDS users as well as determined common characteristics of these classes among a cohort of young adults aged 19-31 years in Texas.

Although we know little about patterns of ENDS use among young adults, there is a sizeable literature base examining cigarette use patterns that we can draw from to inform our understanding of ENDS use patterns. A key change in the tobacco use behaviors of 18-29 year old young adults is the shift towards low-volume smoking (Schane et al., 2009a, 2009b) and in particular the shift towards social smoking. Social smoking is a prevalent sub-pattern of low-volume smoking characterized by smoking primarily in social situations (Moran et al., 2004; Villanti et al., 2017), with 50-80% of young adult smokers reporting social smoking (Jiang et al., 2014; Lisha et al., 2015; Moran et al., 2004; Rath et al., 2012; Song & Ling, 2011). Given the shift towards low-volume cigarette use patterns among young adults (Schane et al., 2009a), there is the possibility that low-volume ENDS use, and also social ENDS use, is a popular pattern among young adults. Data from the 2014 Minnesota Adult Tobacco Survey indicate that among adult smokers who also indicate using ENDS in the past 30 days, more than half (59%) reported using ENDS infrequently or used ENDS  $\leq$  5 days in the past 30 days (Amato et al., 2016). Other

research from the Population Assessment of Tobacco and Health (PATH) study indicates that among adult (18+ years) past 30-day ENDS users, 42.2% report infrequent use of ENDS or use on ‘some days’ and use on 0–2 days in the past 30 days. Among the remaining, 36.5% report moderate ENDS use or use on ‘some days’ and use on >2 of the past 30 days, and only 21.3% report daily ENDS use in the past 30 days (Coleman et al., 2017). Thus, evidence indicates that many adult current ENDS users (including young adult users) also tend to be low-volume ENDS users.

There is also evidence that young adults see ENDS as something that can have a positive social impact (Wallace & Roche, 2018), and that ENDS can play a role in positive social enhancement. That is, young adults perceive that these products facilitate social respect, popularity, liking by peers, as well as help people enjoy social interactions more (Hendricks & Brandon, 2008; Piñeiro et al., 2016; Pokhrel et al., 2014). It is possible then that some of today’s young adult current ENDS users in addition to being low-volume users may also be social ENDS users, a sub-group who like social smokers potentially use ENDS exclusively in social contexts (Shiffman et al., 2015).

To assess social ENDS use as a potential class of ENDS users, we cannot rely on young adults to self-identify as social ENDS users since self-identification may not accurately capture the behavior. Some young adults who identify themselves as social smokers do not behave as such. That is, they do not use cigarettes mainly or only in the company of others, are not light smokers, and show higher symptoms of nicotine dependence compared to social smokers who behave as such (Lisha et al., 2015). Rather, drawing upon existing research on low-volume and social smoking, it is likely that to understand patterns of ENDS use, we must also examine frequency of ENDS use and nicotine dependence. For instance, young adult social smokers generally tend to smoke fewer cigarettes per day than non-social smokers or less than half pack of cigarettes per day

(Lisha et al., 2015; Moran et al., 2004). Further, social smokers are also likely to be non-daily smokers and less dependent on nicotine than are non-social smokers (Moran et al., 2004). It is possible then that social ENDS users, like social smokers, have a high probability of using ENDS infrequently, that is, use ENDS up to 5 days in the past 30 days (Amato et al., 2016; Coleman et al., 2017; Pulvers et al., 2015). It is also possible that there also exists a class of low-volume social ENDS users who are less likely to report ENDS nicotine dependence symptoms, given their lower volume of ENDS use. Thus, there could exist at least two distinct classes of social ENDS users both of whom have a high probability of self-identifying as a social ENDS user. However, one class may have a high probability of using ENDS more frequently and also exhibiting ENDS nicotine dependence symptoms, whereas another class of social ENDS users may have a high probability of reporting ENDS less frequently, and a low probability of reporting ENDS nicotine dependence symptoms. Similarly, there may also exist at least two distinct classes of non-social ENDS users, both of whom have a low probability of self-identifying as a social ENDS user. One class of non-social ENDS users will have a high probability of using ENDS more frequently and a high probability of exhibiting ENDS nicotine dependence symptoms. The second class of non-social ENDS users in addition to having a low probability of self-identifying as social ENDS users, may also have a high probability of using ENDS less frequently, and a low probability of exhibiting ENDS nicotine dependence symptoms.

In addition to self-identifying as a social ENDS user, frequency of ENDS use and ENDS nicotine dependence symptoms, there are some other factors that need to be taken into account while assessing classes of current ENDS users. For instance, research indicates that social smokers are more likely than non-social smokers to co-use other tobacco products, alcohol, and marijuana (Lisha et al., 2015; Villanti et al., 2017). Thus, it is also possible that the two young adult social

ENDS user classes additionally have a high probability of reporting binge alcohol use, marijuana use, and reporting current cigarette use compared to the two other young adult non-social ENDS user classes who would have a low probability of reporting binge alcohol use, marijuana use, and reporting current cigarette use.

Understanding the various classes of young adult current ENDS users is important as this information is critical for existing research to develop tailored tobacco control strategies for various sub-groups of ENDS users. Additionally, it is also important to identify covariates of ENDS user classes and how the classes vary based on factors such as other tobacco use (i.e., cigars, hookah, and smokeless use) and socio-demographics, to further refine tobacco control strategies for specific sub-groups of young adults. Turning again to evidence from the cigarette literature, it is possible that social ENDS users may be more likely to be younger in age, females, racial/ethnic minorities, and 4-year vs. 2-year college students, compared to non-social ENDS users classes (Hukkinen et al., 2009; Li et al., 2018; Lisha et al., 2015; Loukas et al., 2008; Villanti et al., 2017). It is also likely that young adult social ENDS users may be more likely than non-social ENDS users to use other tobacco products such as hookah, cigars, and smokeless tobacco based on evidence from research on cigarettes (Villanti et al., 2017).

In summary, this study aimed to extend existing research by identifying classes of young adult current ENDS users as well as determining common characteristics of a cohort of young adults aged 19-31 years in these classes. Latent Class Analysis was used to identify the classes based on six indicators; 1) self-identifying as a social ENDS user, 2) frequency of ENDS use, 3) ENDS nicotine dependence symptoms, 4) binge alcohol use, 5) marijuana use, and 6) current cigarette use. Based on existing research, I hypothesized that there exist four classes of young adult current ENDS users, including two distinct classes of social ENDS users and two distinct classes

of non-social ENDS users. I also expected that both classes of social ENDS users would have a high probability of self-identifying as a social ENDS user and reporting binge alcohol use, marijuana use, and current cigarette use. However, one class of social ENDS users would have a high probability of using ENDS more frequently and also exhibiting ENDS nicotine dependence symptoms, whereas another class of social ENDS users would have a high probability of reporting ENDS less frequently, and a low probability of reporting ENDS nicotine dependence symptoms. Regarding the two classes of non-social ENDS users, I expected that both would have a low probability of self-identifying as a social ENDS user and of reporting binge alcohol use, marijuana use, and current cigarette use. However, one class of non-social ENDS users would have a high probability of using ENDS more frequently, and a high probability of exhibiting ENDS nicotine dependence symptoms. The second class of non-social ENDS users would also have a high probability of using ENDS less frequently, and a low probability of exhibiting ENDS nicotine dependence symptoms. I also hypothesized that the classes of young adult social ENDS users would be younger in age, females, racial/ethnic minorities, 4-year college students, and likely to use other tobacco products such as hookah, cigars and smokeless tobacco, compared to classes of young adult non-social ENDS users.

## ***Methods***

### *Participants*

Participants were 463 current ENDS-using young adults aged 19-31 years drawn from the Marketing and Promotions across Colleges in Texas Project (Project M-PACT). Project M-PACT is a rapid response surveillance study that collected data from 2014-2019 from a cohort of 5,482 students from 24 Texas colleges. Students were recruited in Fall 2014-Spring 2015 and there were a total of nine surveys, the first eight every six months to Spring 2018 and final survey in Spring

2019. For the purposes of this study, only data from wave 4 (April-May 2016) will be used because participants were asked about their self-identified social ENDS use, one of the important indicators for the LCA analysis, for the first time in the M-PACT study at this wave. Only participants who reported ENDS use in the past 30 days at wave 4 were then assessed on their self-identified social ENDS use. Given the purpose of the study to identify classes of ENDS users, only participants who reported ENDS use in the past 30 days at wave 4 and who had complete data on all of the study covariates were included in the analyses (n=463).

### *Procedure*

Participants were recruited in Fall 2014/Spring 2015 from one of 24 2-year and 4-year colleges in Texas. The 24 colleges from which the young adult cohort was drawn for Project M-PACT were located in five counties including the four largest metropolitan areas in Texas, which are, Austin, Dallas/ Fort Worth, Houston, and San Antonio. Students enrolled in the 24 colleges who met the eligibility criteria were recruited to participate in the online survey via email invitation. The initial email invitation described the purpose of the study and included a link to an eligibility survey. Eligible students who wished to participate in the study provided informed consent and then completed the online survey. Upon completion of the survey, each student received an e-gift card incentive. At wave 4, from which data were drawn for this study, students received a \$20 e-gift card. Further, all students were entered into a drawing to win one of twenty \$50 e-gift cards at all waves. Response rates for wave 4 was 81% (n=4448) of the larger M-PACT cohort (n=5482).

## *Measures*

### *LCA Indicator Variables*

There are 6 indicator variables in the LCA model, all assessed at wave 4. As required by the LCA, the indicator variables were all coded or re-coded into dichotomous variables (0/1; (Nylund-Gibson & Hart, 2014).

### *Self-identifying as a social ENDS user*

Self-identifying as a social ENDS user was assessed at wave 4 with one item developed for project M-PACT, “Do you only use ENDS products (i.e. e cigarettes, vape pens, e-hookah, or mods) as intended (i.e. with nicotine e liquid/e juice) when you are with your friends or in a social situation?” Responses were coded as 0=yes (social ENDS user), 1=no (non social ENDS user).

### *Frequency of ENDS use*

Frequency of ENDS use or past 30-day ENDS use was assessed at wave 4 using an item adapted from the Youth Tobacco Survey [YTS; (Starr et al., 2005)] and the PATH study (Coleman et al., 2017). The current ENDS use item included a description of the range of products under ENDS, including a picture of various ENDS products, followed by asking, “How many of the past 30 days have you used any ENDS product (i.e. an e-cigarette, vape pen, e-hookah, JUUL/pod vape, or mod), even one or two puffs, as intended (i.e. with nicotine cartridges/pods and/or e-liquid/e-juice)?” Using categories defined in existing research (Amato et al., 2016), participants who indicated using ENDS less than or equal to 5 days in the past 30 days, were categorized as infrequent ENDS users and coded as 0. Participants who reported using ENDS from

6-30 days in the past 30 days (intermediate and daily users) were combined together as regular ENDS users and coded as 1 (Amato et al., 2016).

### *ENDS nicotine dependence symptoms*

ENDS nicotine dependence symptoms was assessed at wave 4 using three items. Two items were adapted from DiFranza and colleagues (2002) and one other item was adapted from Heatherton and colleagues (1991) (DiFranza et al., 2002; Heatherton et al., 1991). The first two items asked ever ENDS users “Have you ever felt like you really needed to use an ENDS product?” (0=no and 1=yes), “Have you ever had a strong craving for an ENDS product?” [0=no and 1=yes; (DiFranza et al., 2002). The additional item asked past 30-day ENDS users, “How soon after you wake up do you typically use your first ENDS product?” (Heatherton et al., 1991) Response options for the last item included “within 5 minutes of waking,” “6-30 minutes after waking,” “31-60 minutes after waking,” “61 or more minutes after waking,” and “I am not a daily cigarette smoker.” Consistent with other studies (Loukas et al., 2016), for the purposes of the this dissertation, the last item was re-coded into a dichotomous variable for the LCA (Nylund-Gibson & Hart, 2014) so that only participants who smoked their first ENDS within 30 minutes of waking were coded “1” and all others were coded as “0.” Responses for the three items were summed and participants with no dependence symptoms were assigned a code of 0 and participants who reported at least one dependence symptoms were assigned a code of 1.

### *Binge alcohol*

Participants’ binge alcohol use was assessed at wave 4 with a question adapted from the Monitoring the Future study [MTF; (Schulenberg et al., 2017)], that asked “During the past 14 days, on how many days did you have 5 or more drinks of alcohol in a row?” Answer options

included “0 days,” “1 or 2 days,” “3 to 5 days,” “6 to 9 days,” and “10 to 14 days.” Individuals who reported consuming five or more drinks in a row on one or more days were coded 1, while those who reported no binge alcohol consumption (0 days) were coded 0.

#### *Marijuana use*

Current or past 30-day marijuana use was assessed at wave 4 using an item from the MTF study (Schulenberg et al., 2017), by asking “During the past 30 days, how many occasions, or times, if any, have you used marijuana? (Other names for marijuana are pot and weed.)” Response choices included “0 times,” “1-2 times,” “3-5 times,” “6-9 times,” “10-19 times,” “20-39 times,” and “40 or more times.” Individuals who reported using marijuana one or more times were coded 1, while those who reported no marijuana use (0 times) were coded 0.

#### *Current cigarette use*

Current or past 30-day use of cigarettes was assessed at wave 4 with an item adapted from the PATH study as well as the YTS study (Coleman et al., 2017; Starr et al., 2005). The item asked “On how many days of the past 30 days did you smoke cigarettes?” Use of cigarettes in the past 30 days was scored 0=used on 0 days in the past 30 days or 1=used on 1 or more days in the past 30 days.

#### *Five covariates for the LCA*

Once the emerging classes were identified using the six indicator variables, this study examined covariates of ENDS user classes to determine common characteristics of the young adults in these classes and how the classes varied based on five factors, including socio-demographics of sex, age, race/ethnicity, and college type, and wave 4 past 30-day use of other tobacco products (i.e., cigars, hookah, and smokeless tobacco use).

### *Socio-demographic covariates*

Sex was assessed at wave 1 (0 = female, 1 = male); age was assessed at wave 4 and dichotomized [25 years and above=0 and 19-24 years=1; (Agarwal et al., 2018)]. Race/ethnicity, also assessed at wave 1, was dummy-coded with non-Hispanic white as the reference group (coded as 0) and other groups, Hispanic or Latino, black or African American, Asian, and all other race/ethnicity coded as 1 to facilitate comparison of each racial/ethnic minority group against non-Hispanic white participants. Type of college was also assessed at wave 1 [0 = 2-year college, 1 = 4-year college; (Cooper et al., 2018; Loukas et al., 2018)].

### *Other tobacco use*

Current or past 30-day use of other tobacco products was assessed at wave 4 with an item adapted from the YTS (Starr et al., 2005) and the PATH study (Coleman et al., 2017). The other products assessed included cigars, hookah, and smokeless tobacco. The item asked “On how many days of the past 30 days did you smoke/use [product]?” Use of each tobacco product was scored 0=used on 0 days in the past 30 days or 1=used on 1 or more days in the past 30 days. The scores for all of the three products were summed so that the scores for current use of other tobacco products for each participants ranged from 0-3 (Agarwal et al., 2018).

### *Data Analysis*

Latent Class Analysis was conducted in Mplus 8 (Collins, 2010; Muthén & Muthén, 2018; Villanti et al., 2017) to identify classes of young adult current ENDS users as well as to determine common characteristics of a cohort of young adults aged 19-31 years in these classes. Latent Class Analysis is a technique that is commonly used to identify distinct classes of behaviors, such as alcohol and tobacco use (Rinker & Neighbors, 2015; Villanti et al., 2017). Rather than relying on

a single observed variable to define behavior, this analysis technique identifies a latent variable comprising a variety of indicator variables to portray intersections and complexity of behavior in a person (Lanza & Rhoades, 2013). The best fitting model was selected by running models with a successive number of classes from two to four and comparing each of the models on various fit indices as well as parsimony of interpretation. In selecting the best fitting model, absolute tests of model fit were considered, which included the Bayesian Information Criteria (BIC) and the Akaike Information Criterion (AIC), for both of which smaller values are ideal (Nylund-Gibson & Choi, 2018). I also took into account entropy that is a measure of classification quality and for which values as close to 1 as possible are considered ideal (Celeux & Soromenho, 1996). Lastly, I also took into consideration the Vuong-Lo-Mendell-Rubin test (VLMR) and the bootstrapped likelihood ratio test (BLRT). When these two tests indicate a non-significant p-value, the previous class is the better fitting model (Collins, 2010).

#### *Examining the covariates in the LCA*

Once I determined the best fitting and most parsimonious model, I added all the covariates to that model simultaneously to explore the characteristics of ENDS user classes and how the classes vary based on factors such as socio-demographics and current use of other tobacco products, that is, use of cigars, hookah, and smokeless tobacco (Nylund-Gibson & Hart, 2014). I examined the associations between the covariates and the latent classes using the R3STEP command to run the multinomial logistic regression in M-PLUS 8 (Muthén & Muthén, 2018). The multinomial logistic regression is a comparison of the probability of being in a particular latent class compared with a chosen reference latent class (dependent variable), so that all the values of the covariates (independent variables) are compared with the reference class (Nylund-Gibson & Hart, 2014).

### *Missing data*

This study had 480 eligible participants who were current ENDS users at wave 4. Of these, 17 participants had incomplete data on the five covariates and thus were dropped from all analyses (Nylund-Gibson & Hart, 2014), resulting in a final sample of 463 current ENDS users. A full-information maximum likelihood (FIML) approach was used; thus, although there were two participants out of the 463 missing data on one of more of the six indicator variables, these were handled within the analysis model and these participants were not removed from the analyses (Collins, 2010; Nylund-Gibson & Hart, 2014).

### **Results**

Participant socio-demographic factors are displayed in Table 1. Of the 463 participants, half were female (52.9%), they were on average 22.30 years old ( $M=22.30$ ,  $SD=2.30$ ), about 35.6% identified as white, and 91.6% attended a 4-year college. Notably, the socio-demographic profiles of the 463 participants in the study sample were comparable to the overall cohort of M-PACT at wave 4, except the present sample appears to include more males than the overall M-PACT sample (see Table 1).

*Table 1. Socio-demographic comparison of the entire M-PACT cohort at wave 4 (n= 4448) and the study sample (n= 463).*

<i>Socio-demographics</i>	<i>Entire M-PACT cohort at wave 4 (n=4448)</i>	<i>Dissertation sample at wave 4 (n=463)</i>
Sex	64.2% Female	52.9% Female
Age at Wave 4	M= 22.31, SD= 2.32	M= 22.30, SD= 2.30
Race/Ethnicity	35.3% White 31.1% Hispanic 7.9% African American 18.3% Asian 7.5% Other	35.6% White 34.6% Hispanic 5% African American 14.7% Asian 10.2% Other
College Type (4-year v/s 2-year)	92.9% attending a 4-year college	91.6% attending a 4-year college

#### *Latent Class Formation*

Table 2 presents the model fit statistics for all models. Models for 2-class through 4-class solutions were run and after comparing all the fit statistics and taking parsimony of interpretation into account, a 3-class solution provided the best indication of model fit. In the best fitting model, the AIC and the BIC are the lowest among all the models, the entropy is the closest to 1, and the VLMR and BLRT statistics are significant (Celeux & Soromenho, 1996; Collins, 2010; Nylund-Gibson & Choi, 2018). Thus, upon examination of Table 2, I rejected the 4-class model because the AIC was larger than the 3-class solution, the BIC was larger than both the 2-class and the 3-class solution, the entropy was lower than the 3-class solution, and the VLMR and BLRT statistics were not significant. Compared with the 2-class solution, the 3-class solution had a lower AIC, higher entropy (closer to 1), and BLRT and VLMR tests results were significant. Thus, even though the BIC was the smallest for a 2-class solution, all the other parameters indicated a 3-class solution as the best fit. Finally, I took into account parsimony of interpretation of classes, which also indicated a 3-class solution as the best fit.

*Table 2. Model fit statistics for the 2-class through the 4-class solutions.*

	AIC	BIC	Entropy	VLMR <i>p</i>	BLRT <i>p</i>
2-class model	3635.757	<b>3689.548</b>	0.570	<b>0.0000</b>	<b>0.0000</b>
3-class model	<b>3608.477</b>	3691.232	<b>0.587</b>	<b>0.0185</b>	<b>0.0204</b>
4-class model	3613.633	3725.352	0.580	0.5877	0.5800

*Note. The highlighted values indicate the best fitting values during model comparison.*

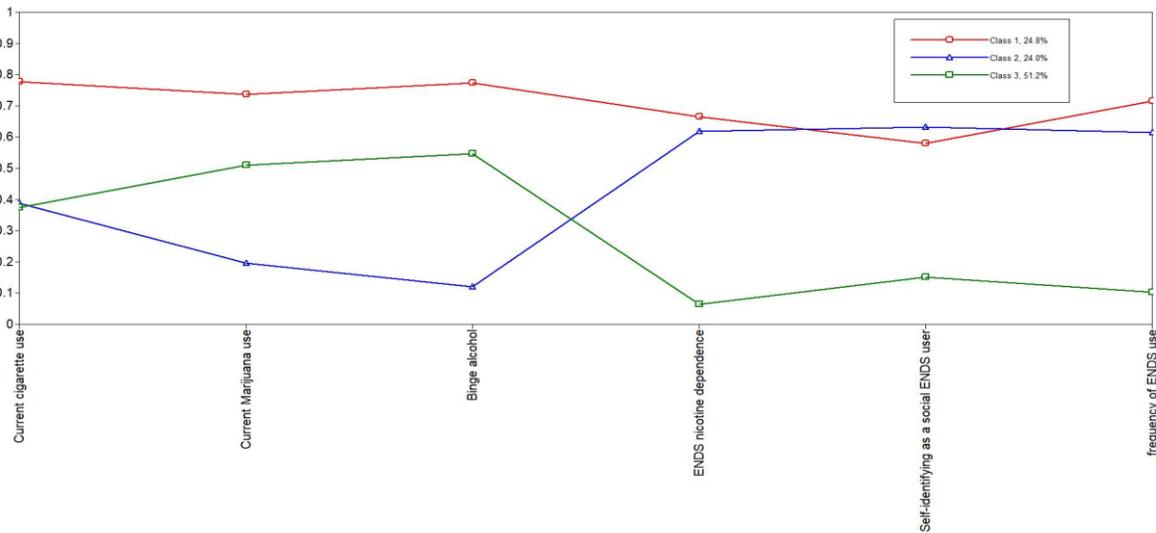
### *Identification of latent classes*

Both Table 3 and Figure 1 show the item-response probabilities for each of the latent classes in the best fitting 3-class solution. I labeled the three classes as: non-nicotine dependent social ENDS users, high-risk poly-tobacco and substance users, and nicotine dependent ENDS users. Non-nicotine dependent social ENDS users comprised the highest proportion of the study sample (n=237, 51.2%). Non-nicotine dependent social ENDS users had a high probability of self-identifying as a social ENDS user, a low probability of exhibiting ENDS nicotine dependence symptoms, a low probability of using ENDS more than 6 days in the past 30 days, had approximately a 50-50 probability of binge alcohol and marijuana use, and a low probability of current cigarette use. The next group was the high-risk poly-tobacco and substance users (n=115, 24.8%), who reported a 50-50 probability of self-identifying as a social ENDS user and a high probability of ENDS nicotine dependence symptoms. This group also had a high probability of using ENDS more than 6 days in the past 30 days, and a high probability of binge alcohol and marijuana use, as well as current cigarette use. The last group was the nicotine dependent ENDS users (n= 111, 24.0%), who reported a low probability of self-identifying as a social ENDS user, a high probability of exhibiting ENDS nicotine dependence symptoms as well as using ENDS at least 6 days or more in the past 30 days. However, the nicotine dependent ENDS users also had a low probability of binge alcohol and marijuana use, as well as current cigarette use (see Table 3 and Figure 1).

Table 3. Item response probabilities for the 3-class solution

	<i>Non-nicotine dependent social ENDS users</i> <i>n= 237 (51.2%)</i>	<i>High-risk poly-tobacco and substance users</i> <i>n= 115 (24.8%)</i>	<i>Nicotine dependent ENDS users</i> <i>n= 111 (24.0%)</i>
Self-identifying as a social ENDS user (1= non-social ENDS user)	<b>0.151</b>	0.579	<b>0.630</b>
ENDS nicotine dependence symptoms	<b>0.062</b>	<b>0.664</b>	<b>0.623</b>
Frequency of ENDS use (1= 6 days or more)	<b>0.101</b>	<b>0.715</b>	<b>0.613</b>
Binge alcohol use	0.545	<b>0.772</b>	<b>0.122</b>
Current marijuana use	0.508	<b>0.737</b>	<b>0.194</b>
Current cigarette use	<b>0.373</b>	<b>0.776</b>	<b>0.389</b>

Figure 1. Latent-class model of item-response probability patterns for current ENDS user classes (N=463)



*Covariates of latent classes-logistic regression results*

In the next part of the analyses, all socio-demographics and other tobacco use covariates were included as auxiliary predictor variables simultaneously in the 3-class LCA model, with each of the three latent classes serving as a dependent outcome, to facilitate comparison across all the three classes. Three models were examined, each with a different reference category for the latent

class dependent variable. In model 1 (Table 4), high-risk poly-tobacco and substance users were the reference category; in model 2 (Table 5), the nicotine dependent ENDS users were the reference category; and in model 3 (Table 6), the non-nicotine dependent social ENDS users were the reference category. Results from the three multinomial logistic regression analyses are reported in Tables 4-6. Males had higher odds of being classified in the high-risk poly-tobacco and substance user class compared to the odds of being in the nicotine dependent ENDS user class or non-nicotine dependent social ENDS user class (see Table 4). Further, students attending a 4-year college had higher odds of being classified in the nicotine dependent ENDS user class compared to the odds of being classified in the high-risk poly-tobacco and substance user class (see Table 5). Moreover, younger young adults aged 18-24 years old had higher odds of being classified in the non-nicotine dependent social ENDS user class compared to the nicotine dependent ENDS user class (see Table 6). Regarding race/ethnicity, compared to whites, Asian and other race had higher odds of being classified in either the nicotine dependent ENDS user class or the non-nicotine dependent social ENDS user class compared to the odds of being classified in the high-risk poly-tobacco and substance users (see Tables 5&6). Being Hispanic/Latino and African American was not associated with an increased likelihood of membership in any of the latent user classes. Lastly, each increase in the number of other tobacco products used (among cigars, hookah, and smokeless tobacco) was associated with higher odds of being classified in the high-risk poly-tobacco and substance user class compared to the odds of being classified in either the nicotine dependent ENDS user class or the non-nicotine dependent social ENDS user class (see Table 4). In fact, each increase in the number of other tobacco products used was associated with with 3.71 times higher odds of being classified in the high-risk poly-tobacco and substance user class compared to the odds of being classified in the non-nicotine dependent social ENDS user class (see Table 6). In

summary, males, those attending 2-year colleges, young adults aged 25 years and above, whites, and other tobacco users, had higher odds of being classified in the relatively riskier classes of high-risk poly-tobacco and substance users and nicotine dependent ENDS users, compared to the odds of being classified in the lower risk class of non-nicotine dependent social ENDS users.

*Table 4. Multinomial logistic regression results with the latent high-risk poly-tobacco and substance user class as a reference group.*

Factor	High-risk poly-tobacco and substance users	Nicotine dependent ENDS users	Non-nicotine dependent social ENDS users
AOR			
Male (vs. female)	Reference	0.36**	0.42**
Four-year college (vs. Two-year college)		3.44	2.17
Age 19-24 years (vs. 25 years and above)		0.53	1.26
Race/Ethnicity (vs. white)			
Hispanic/Latino (vs. white)		1.43	1.68
Asian (vs. white)		2.17	2.54
African American (vs. white)		0.51	1.49
Other race (vs. white)		3.53	4.66
Other Tobacco use (scored from 1-3)		0.20**	0.27**

*Note. The socio-demographics were coded as 0=female, 1=male; 25 years and above=0, 19-24 years=1; race/ethnicity was dummy-coded with non-Hispanic white as the reference group (coded as 0) and other groups, Hispanic or Latino, black or African American, Asian, and all other race/ethnicity coded as 1 to facilitate comparison of each racial/ethnic minority group against non-Hispanic white participants; 0=2-year college, 1=4-year college; the scores for current use of other tobacco products for each participants ranged from 0-3. \* $p < .05$ ; \*\* $p \leq .001$  indicate significant findings.*

Table 5. Multinomial logistic regression results with the latent nicotine dependent ENDS user class as a reference group.

Factor	High-risk poly-tobacco and substance users	Nicotine dependent ENDS users	Non-nicotine dependent social ENDS users
AOR			
Male (vs. female)	2.80	Reference	1.17
Four-year college (vs. Two-year college)	0.29*		0.63
Age 19-24 years (vs. 25 years and above)	1.88		2.38
Race/Ethnicity (vs. white)			
Hispanic/Latino (vs. white)	0.70		1.18
Asian (vs. white)	0.46		1.17
African American (vs. white)	1.95		2.90
Other race (vs. white)	0.28*		1.32
Other tobacco use (scored from 1-3)	4.89		1.32

Note. The socio-demographics were coded as 0=female, 1=male; 25 years and above=0, 19-24 years=1; race/ethnicity was dummy-coded with non-Hispanic white as the reference group (coded as 0) and other groups, Hispanic or Latino, black or African American, Asian, and all other race/ethnicity coded as 1 to facilitate comparison of each racial/ethnic minority group against non-Hispanic white participants; 0=2-year college, 1=4-year college; the scores for current use of other tobacco products for each participants ranged from 0-3. \* $p < .05$ ; \*\* $p \leq .001$  indicate significant findings.

Table 6. Multinomial logistic regression results with the latent non-nicotine dependent social ENDS user class as a reference group.

Factor	High-risk poly-tobacco and substance users	Nicotine dependent ENDS users	Non-nicotine dependent social ENDS users
AOR			
Male (vs. female)	2.38	0.85	Reference
Four-year college (vs. Two-year college)	0.46	1.58	
Age 19-24 years (vs. 25 years and above)	0.80	0.42**	
Race/Ethnicity (vs. white)			
Hispanic/Latino (vs. white)	0.59	0.85	
Asian (vs. white)	0.39*	0.85	
African American (vs. white)	0.67	0.34	
Other race (vs. white)	0.22**	0.76	
Other tobacco use (scored from 1-3)	3.71*	0.76	

Note. The socio-demographics were coded as 0=female, 1=male; 25 years and above=0 and 19-24 years=1; race/ethnicity was dummy-coded with non-Hispanic white as the reference group (coded as 0) and other groups, Hispanic or Latino, black or African American, Asian, and all other race/ethnicity coded as 1 to facilitate comparison of each racial/ethnic minority group against non-Hispanic white participants; 0=2-year college, 1=4-year college; the scores for current use of other tobacco products for each participants ranged from 0-3. \* $p < .05$ ; \*\* $p \leq .001$  indicate significant findings.

## **Discussion**

Existing research has just begun to scratch the surface on patterns of ENDS use among all adults (Amato et al., 2016) and this study is the first to identify current ENDS user classes and their common characteristics among a cohort of young adults in Texas. Findings are consistent with existing research indicating that ENDS users are not a homogenous group (Amato et al., 2016). Contrary to expectations that there would emerge at least four distinct classes of young adult current ENDS users, findings identified three distinct classes of current ENDS users. However, in partial agreement with expectation, two of the identified classes were comprised of addicted current ENDS users and one was comprised of non-addicted social ENDS users. While existing research demonstrates the need to tailor tobacco control messaging for different groups of young adult tobacco users (Boynton et al., 2016), the current findings suggest that these should be specifically tailored to three different classes of young adult ENDS users. Further, tobacco control efforts should be developed for certain population sub-groups such as males, young adults attending 2-year colleges, young adults aged 25 years and above, whites, and other tobacco users. This is because the aforementioned groups are likely to have higher odds of being classified in the relatively riskier classes of either the high-risk poly-tobacco and substance users or the nicotine dependent ENDS users, compared to odds of being classified in the lower risk class of non-nicotine dependent social ENDS users.

Consistent with other emerging evidence that cigarette smokers are not a homogenous group and that social smokers are a distinct class from other smokers (Villanti et al., 2017), this study found that there exist a class of young adult non-nicotine dependent social ENDS users, who formed the largest class in this study sample (51.2%). Given that this class of ENDS users had a low probability of exhibiting nicotine dependence symptoms and a high probability of using ENDS

on 1-5 days in the past 30 days, it is possible that this class of non-nicotine dependent social ENDS users are experimenting with ENDS use. Young adulthood is a period characterized by transitions and experimentation and there is indeed evidence that young adults' use of ENDS is not stable (Agarwal et al., 2018; Arnett, 2014; Arnett & Tanner, 2016; Orlando et al., 2004; Stanton et al., 2020). Therefore, it is possible that some of these young adults will stop using ENDS, but some of them could also become addicted users. Like social smokers, there are concerns that this group might strongly demarcate their identity from other ENDS users and also be less likely than nicotine dependent social ENDS users to realize that they are at risk for nicotine dependence (Berg et al., 2010; Hoek et al., 2013). In other words, like low-volume smokers and social smokers (Berg et al., 2010; Hoek et al., 2013), these ENDS users might not identify as ENDS users or give importance to health concerns associated with even low-volume ENDS use, foremost of which is the risk of nicotine dependence (Etter et al., 2013) and the negative impact of nicotine on brain development (Yuan et al., 2015). Thus, appropriate tobacco control messaging is needed, tailored specifically to them. Further, longitudinal research is also needed to understand transition patterns of the non-nicotine dependent social ENDS user class to determine the long-term ENDS use trajectories of this class and understand which young adults will continue to use ENDS and those that will not.

Interestingly, the high-risk poly-tobacco and substance users formed almost a quarter of current ENDS users falling into this group (24.8%). Existing research indicates that poly-tobacco use is more common than single product use and poly-tobacco users typically comprise more than 50% of ENDS users among adolescents and young adults (King et al., 2018; Loukas et al., 2016). However, this class comprised only a quarter in this sample, which could be because I assessed use of alcohol and marijuana in addition to cigarettes when identifying classes of current ENDS

users, something the existing research has not yet examined among young adult current ENDS users. Nonetheless, this finding is concerning given that this class had a high probability of past 30-day cigarette use, current marijuana use, binge alcohol use, along with ENDS nicotine dependence symptoms and using ENDS on more than 5 days in the past 30 days. This class provides evidence for comorbidity of risky behaviors among current ENDS users and findings are consistent with Problem Behavior Theory (PBT), indicating that young adults who use one class of substance may have increased likelihood of use of another (Jessor, 1987; Jessor & Jessor, 1977). Recent research has also found strong evidence that ENDS use may be associated with prospective use of cigarettes among youth and young adults (Loukas et al., 2018; Niaura et al., 2020; Watkins, Glantz, & Chaffee, 2018). Therefore, even if some young adults in this class are experimenting with ENDS currently, they may still be at risk for persistent ENDS use, nicotine addiction from the nicotine in ENDS, as well as the risk of using cigarettes in the future. Future research should examine transitions patterns of this class longitudinally. This class is especially important to target in tobacco control, given that they have a high probability of not only using ENDS more frequently, that is, using ENDS on more than 5 days in the past month, and having ENDS nicotine dependence symptoms, but also being current cigarette, marijuana and binge alcohol users.

The last class of current ENDS users were the nicotine dependent ENDS users, comprising close to a quarter of the sample (24.0%). Based on evidence from existing research, ENDS nicotine dependence is associated with increased use of ENDS among youth as well as adults (Morean et al., 2018; Vogel, Cho, et al., 2020). Therefore, this class might be at a risk for persistent use of ENDS over time given that they have high probability of exhibiting ENDS nicotine dependence, which makes them an important target for tobacco control interventions.

Beyond identifying three unique classes of young adults current ENDS users, I also examined the characteristics of the various ENDS user classes based on factors such as socio-demographics and other tobacco use, that is, use of cigars, hookah, and smokeless tobacco. I found that males, whites, young adults aged 25 and above, those attending 2-year colleges, and users of other tobacco products, had higher odds of being in the relatively riskier classes of either the high-risk poly-tobacco and substance users or the nicotine dependent ENDS users, compared to the odds of being classified in the lower risk class of non-nicotine dependent social ENDS users. The socio-demographic findings are consistent with existing research on cigarettes, which also demonstrates that males and whites are likely to be classified in the heavier tobacco use classes (Scheier & Komarc, 2020). The finding on young adults attending 2-year colleges also extends the existing research indicating that 2-year college students have overall riskier smoking behaviors compared to students enrolled in 4-year universities (Li et al., 2018; Loukas et al., 2018) by suggesting that attendance at 2-year colleges is associated with risky ENDS use behaviors as well. Students at 2-year colleges tend to be older (Phillippe & Sullivan, 2005) than those in 4-year colleges; thus, it is not surprising that older young adults aged 25 years and above and those attending 2-year colleges had higher odds of being classified in the riskier class of nicotine dependent ENDS users and high-risk poly-tobacco and substance users, compared to the less risky class of non-nicotine dependent social ENDS users. The finding is in agreement with existing evidence that the younger 18-24 year old young adults may be experimenting with ENDS, which is why they are likely to be classified in the lower risk class of non-nicotine dependent social ENDS users, a pattern that is consistent with the hypothesis and evidence from existing research on ENDS use (Agarwal et al., 2018; Stanton et al., 2020). Lastly, it is also important to note that each increase in the number of other tobacco products used by young adults was associated with higher odds of being classified in either

the high-risk poly-tobacco and substance user class or the nicotine dependent social ENDS user class, compared to non-nicotine dependent social ENDS user class. The finding is consistent with evidence from the PBT (Jessor & Jessor, 1977) and highlights the importance of considering comorbidity of risky tobacco behaviors among young adult current ENDS users while designing overall tobacco control strategies.

Some strengths of the current study are the use of a diverse sample of young adults from multiple cities across Texas and the use of LCA in understanding classes of young adult current ENDS users, something that the existing research has not examined to date. The study is the first to identify three distinct classes of young adult current ENDS users. The study also found that males, whites, young adults aged 25 and above, those attending 2-year colleges, and other tobacco users had higher odds of being in the relatively riskier classes of either the high-risk poly-tobacco and substance users or nicotine dependent ENDS users, compared to the odds of being classified in the lower risk class of non-nicotine dependent social ENDS users. However, there are some limitations. One limitation of the study was that the indicator variables were dichotomized for the LCA given the sample size to maximize power for the analysis. Future research should replicate the findings with larger samples and utilize Latent Profile Analysis, which uses categorical indicator variables, to further understand the characteristic breakdown of the current classes. Another limitation is that the study utilized data from one time point to understand current ENDS user classes. Longitudinal research is needed to understand transition patterns of the three identified classes, and assess which classes of young adults in the classes are experimenting with ENDS currently and which classes continue to use ENDS over a period of time. Longitudinal research for example will help find out whether the riskier classes of nicotine dependent ENDS

users and high-risk poly-tobacco and substance users continue to use ENDS over a period of time, and what sub-groups are likely to.

In summary, this is the first study to conduct an examination of classes of young adult current ENDS users. Results underscore the heterogeneity among young adult current ENDS users and the need for development of distinct tobacco control messaging and intervention strategies tailored to different sub-groups of young adult ENDS users. For instance, educating the non-nicotine dependent social ENDS users on health concerns associated with even low-volume ENDS use, which includes the risk of nicotine dependence (Etter et al., 2013) and the negative impact of nicotine on brain development (Yuan et al., 2015), will help in limiting the tobacco related burden among this class. Similarly, tailoring messaging regarding the risk for persistent or even increased use of ENDS especially among older young adults aged 25 years and above could help with reducing the tobacco related burden among the nicotine dependent ENDS users. Lastly, tobacco control interventions that include messaging on alcohol and marijuana use tailored especially towards males and other tobacco users will also assist with mitigating the tobacco related burden among the high-risk poly-tobacco and substance users.

## Chapter 5: Study 2

### Young adult current Electronic Nicotine Delivery System (ENDS) user latent classes prospectively predict ENDS use one year later

#### *Abstract*

*Introduction.* Despite the increasing popularity of Electronic Nicotine Delivery Systems (ENDS), research is lacking on patterns of ENDS use and their role in subsequent ENDS use behaviors. The aim of this study was to identify if membership in three latent ENDS user classes, which were non-nicotine dependent social ENDS users, high-risk poly-tobacco and substance users, and nicotine dependent ENDS users, predicted subsequent current ENDS use, ENDS nicotine dependence symptoms, and frequency of ENDS use one year later, among a cohort of young adults in Texas. *Methods.* Participants were 424 young adults aged 19-31 years, who were drawn from waves 4 (April-May 2016) and 6 (April-May 2017) of the Marketing and Promotions across Colleges in Texas project (Project M-PACT), which collected data from a cohort of college students across Texas. Two separate logistic regression analyses (one for wave 6 current ENDS use and one for wave 6 ENDS nicotine dependence symptoms outcome variables) and one multiple regression analysis (for the frequency of ENDS use outcome variable) were used to test the hypotheses that classification in the high-risk poly-tobacco and substance user class would predict higher odds of subsequent current ENDS use, ENDS nicotine dependence symptoms, and using ENDS more frequently one year later, compared to the other two classes, even after controlling for socio-demographics and other current tobacco use (use of cigars, hookah, smokeless tobacco) at baseline. In all regression models, the latent class membership dummy variable served as the independent variable, and socio-demographics of sex, age, race/ethnicity, and college type and wave 4 past 30-day use of other tobacco products (i.e., cigars, hookah, and smokeless tobacco use) were included as covariates simultaneously. *Results.* Results confirmed the hypothesis that

membership in the highest risk class of high-risk poly-tobacco and substance users elevated risk for subsequent current ENDS use, ENDS nicotine dependence symptoms, and using ENDS more frequently one year later, compared to the lowest risk class of non-nicotine dependent social ENDS users, after accounting for the socio-demographics and other tobacco use covariates. Further, findings also confirmed that hypothesis that membership in the highest risk class of high-risk poly-tobacco and substance users also elevated risk for subsequent ENDS nicotine dependence symptoms and frequency of ENDS use one year later, compared to the nicotine dependent ENDS users, after accounting for the socio-demographics and other tobacco use covariates. *Implications.* Tobacco control messaging and interventions should be tailored towards the high-risk poly-tobacco and substance users and the nicotine dependent ENDS users.

### ***Introduction***

There has been a steady increase in the use of Electronic Nicotine Delivery Systems (ENDS) from 2014-2018 among young adults, who have the highest prevalence of current ENDS use among adolescents and all adults (Dai & Leventhal, 2019b; Kasza et al., 2017; Stanton et al., 2020). However, we know little about long-term patterns of ENDS use among young adults, despite there being recent evidence that ENDS users are not a homogenous group (Amato et al., 2016). Most research examines correlates and/or predictors of use/non-use, which limits the examination of the various patterns of ENDS use behaviors (Coleman et al., 2019; Stanton et al., 2020). Research is thus lacking on what patterns of ENDS use are stable over time and what patterns are associated with ENDS cessation over time. Understanding characteristics and long-term trajectories of various patterns of ENDS use is critical to developing tailored tobacco control strategies and messaging for different classes of young adult users.

Limited longitudinal research tracking changes in ENDS use indicates that young adults' use of ENDS is not stable; that there are new users of ENDS during young adulthood, but also that ENDS use desists or declines during this developmental period (Agarwal et al., 2018; Stanton et al., 2020). However, we do not know what patterns of use are likely to be sustained and which ones are likely to desist over time. Further, existing research has just begun to scratch the surface on patterns of use behaviors defined by frequency of ENDS use in the past 30 days (Amato et al., 2016). Recently one unpublished dissertation study (see Chapter 4) found that there exist three distinct latent classes of young adult current ENDS users, which are non-nicotine dependent social ENDS users, high-risk poly-tobacco and substance users, and nicotine dependent ENDS users. Non-nicotine dependent social ENDS users had a high probability of self-identifying as a social ENDS user, a low probability of exhibiting ENDS nicotine dependence symptoms, a low probability of using ENDS 6 or more days in the past 30 days, approximately a 50-50 probability of binge alcohol and marijuana use, and a low probability of current cigarette use. The high-risk poly-tobacco and substance users reported a 50-50 probability of self-identifying as a social ENDS user, a high probability of ENDS nicotine dependence symptoms, of using ENDS 6 or more days in the past 30 days, of binge alcohol and marijuana use, and of current cigarette use. Finally, the nicotine dependent ENDS users reported a low probability of self-identifying as a social ENDS user, a high probability of exhibiting ENDS nicotine dependence symptoms, and using ENDS at least 6 days or more in the past 30 days. Moreover, the nicotine dependent ENDS users also had a low probability of binge alcohol and marijuana use, as well as current cigarette use. Despite identification of these three classes of young adult ENDS users, no research examines if membership in these latent classes prospectively predicts ENDS use among young adults as they age. Thus, the current study extended existing research by examining if membership in the three

aforementioned ENDS user classes predicted subsequent current (i.e., past 30-day) ENDS use, ENDS nicotine dependence symptoms, and frequency of ENDS use one year later.

Although we do not know about the role of young adult current ENDS user latent classes in prospectively predicting subsequent ENDS use, there is a sizeable literature base examining cigarette use patterns that we can draw from to inform our understanding of these associations. For example, research suggests that low-volume smoking patterns such as light and intermittent smoking (defined as consumption of up to 5 cigarettes per day), including social smoking, are not as stable as non-smoking and heavy smoking over time (Hukkinen et al., 2009; White et al., 2009; Zhu et al., 2003). Moreover, light and intermittent smokers are more likely than their counterparts to transition to non-use over time (White et al., 2009). Emerging evidence on ENDS use also indicates similar patterns of desistance in young adults' use of ENDS. Research with adults from the Population Assessment of Tobacco and Health (PATH) study shows that there is a high likelihood of desistance of ENDS among adults who are infrequent ENDS users (that is, use of ENDS on some days or up to 2 days within the past 30 days) within a one year period (Coleman et al., 2019). Taken together, it is possible that non-nicotine social ENDS users who use ENDS less frequently, that is, up to 5 days in the past 30 days, will eventually stop using ENDS over time, compared to the high-risk poly-tobacco and substance users as well as the nicotine-dependent ENDS users. As such, the non-nicotine dependent social ENDS users would be less likely than the other two classes of users to use ENDS one year later, to have subsequent ENDS nicotine dependence symptoms given their low volume of ENDS used, and use ENDS less frequently one year later.

While there is evidence for desistance in low-volume smoking patterns, there is also evidence for sustained cigarette use among youth and young adult smokers, particularly those who

show symptoms of nicotine dependence (Morean et al., 2018; Vogel, Cho, et al., 2020). Additionally, research on adults aged 18 years and older from the PATH study shows that daily users of ENDS are more likely to continue using ENDS over a one year period compared to non-daily ENDS users (Coleman et al., 2019). Evidence thus suggests that having ENDS nicotine dependence symptoms and using ENDS more frequently may be associated with sustained ENDS use over time. Therefore, given that the high-risk poly-tobacco and substance users and the nicotine dependent ENDS users have a high probability of ENDS nicotine dependence symptoms as well as using ENDS more frequently (that is, 6 days or more in the past 30 days) at baseline, these two classes of users may be more likely to sustain ENDS use over time, compared to the non-nicotine dependent social ENDS users.

When comparing the nicotine dependent ENDS user class and the high-risk poly-tobacco and substance user class, the latter may be more likely to have the highest risk of sustaining ENDS use over time, not only because they show symptoms of dependence but also because of comorbidity with other tobacco products and substances. According to the Problem Behavior Theory (PBT), young adults who use one class of substance may have increased likelihood of use of another (Jessor, 1987; Jessor & Jessor, 1977). Moreover, recent evidence indicates that continued use of ENDS is more likely among groups that use cigarettes and other tobacco products compared to those groups who did not use cigarettes along with other tobacco products (Stanton et al., 2020). Taken together, the high-risk poly-tobacco and substance users are likely to have the highest risk of sustaining ENDS use across time, compared to the other two classes of young adult current ENDS users.

In summary, the purpose of this study was to examine if membership in three ENDS user classes predicts subsequent ENDS use behaviors. The three latent classes derived from an

unpublished dissertation (see Chapter 4) were, non-nicotine dependent social ENDS users, high-risk poly-tobacco and substance users, and nicotine dependent ENDS users. I assessed if membership in the latent classes predicted three outcomes one year later, which were past 30-day ENDS use, ENDS nicotine dependence symptoms, and frequency of ENDS use. I also controlled for relevant socio-demographics and other tobacco use (i.e., cigars, hookah, and smokeless use) covariates. These covariates were selected based on research on tobacco use including ENDS use indicating that, females, younger people, racial/ethnic minorities, and 4-year college students have less risky tobacco use behaviors compared to their counterparts (Hukkinen et al., 2009; Kasza et al., 2017; Li et al., 2018; Lisha et al., 2015; Loukas et al., 2008; Villanti et al., 2017). Further, there is also evidence that young adult smokers are more likely than non-smokers to use other tobacco products such as hookah, cigars, and smokeless tobacco, and that other tobacco users are more likely to use ENDS in future (Agarwal et al., 2018; Villanti et al., 2015). Thus, I hypothesized that classification in the high-risk poly-tobacco and substance user class would predict higher odds of subsequent past 30-day ENDS use, ENDS nicotine dependence symptoms, and using ENDS more frequently one year later, compared to both the non-nicotine dependent social ENDS users and the nicotine dependent ENDS users, even after controlling for socio-demographics and other current tobacco use (use of cigars, hookah, smokeless tobacco) at baseline.

## ***Methods***

### *Participants*

Participants were 424 young adults drawn from waves 4 (April-May 2016) and 6 (April-May 2017) of a larger study called Project M-PACT. Wave 4 data were collected in April-May 2016 and Wave 6 data were collected one year later in April-May 2017. Self-identifying as a social ENDS user, one of the main factors in the original Latent Class Analysis (LCA) that identified the

three classes of ENDS users, was first assessed at wave 4. For this reason, waves 4 and 6 data were used for the present study to examine how latent class membership predicted subsequent ENDS use one year later. Note that a total of 480 participants self-identified as past 30-day ENDS users at wave 4. However, 17 participants had incomplete data on the five study covariates and thus were dropped from LCA analyses [see Chapter 4; (Nylund-Gibson & Hart, 2014)]. An additional 39 participants were missing data on past-30 day ENDS use at wave 6 and also were dropped from analyses. Thus, 424 participants were retained for the current study.

### *Procedure*

Participants were recruited in Fall 2014/Spring 2015 from one of 24 2-year and 4-year colleges in Texas. The 24 colleges from which the young adult cohort was drawn for Project M-PACT were located in five counties including the four largest metropolitan areas in Texas, which are, Austin, Dallas/ Fort Worth, Houston, and San Antonio. Students enrolled in the 24 colleges who met the eligibility criteria were recruited to participate in the online survey via email invitations. The initial email invitation described the purpose of the study and included a link to an eligibility survey. Eligible students who wished to participate in the study provided informed consent and then completed the online survey. Upon completion of the survey, each student received an e-gift card incentive. At waves 4 and 6, from which data were drawn for this study, students received a \$20 e-gift card. Further, all students were entered into a drawing to win one of twenty \$50 e-gift cards at all waves. The response rate for wave 4 was 81% (n=4448) and for wave 6 was 80% (n=4384) of the larger M-PACT cohort (N=5482).

## *Measures*

### *Indicator Variables that originally formed the current ENDS user classes in the unpublished dissertation study*

There were 6 indicator variables in the LCA model in the unpublished dissertation study (see Chapter 4), all assessed at wave 4 of project M-PACT; which were- self-identifying as a social ENDS user, ENDS nicotine dependence symptoms, frequency of ENDS use, binge alcohol use, marijuana use, and current cigarette use. As required by the LCA, the indicator variables were all coded or re-coded into dichotomous variables for the LCA classes in the unpublished dissertation study [0/1; (Nylund-Gibson & Hart, 2014)]. The six indicator variables resulted in three distinct latent classes of young adult current ENDS users, which are, non-nicotine dependent social ENDS users, high-risk poly-tobacco and substance users, and nicotine dependent ENDS users (see Chapter 4).

### *Independent Variables*

The three latent classes formed the independent variable for the regression analyses in the current study (see Chapter 4 for detailed description of independent variables). The three latent classes served as independent variable and were dummy coded so that the highest risk class, that is, high-risk poly-tobacco and substance users were the reference group (coded as 0), and the nicotine-dependent ENDS users and the non-nicotine dependent social ENDS users were coded as 1.

## *Socio-demographics and other tobacco use covariates*

### *Socio-demographic covariates*

Sex was assessed at wave 1 (0 = female, 1 = male); age was assessed at wave 4 and dichotomized [25 years and above=0 and 19-24 years=1; (Agarwal et al., 2018)]. Race/ethnicity, also assessed at wave 1, was dummy-coded with non-Hispanic white as the reference group (coded as 0) and other groups, Hispanic or Latino, black or African American, Asian, and all other race/ethnicity coded as 1 to facilitate comparison of each racial/ethnic minority group against non-Hispanic white participants. Type of college was also assessed at wave 1 and dichotomized [0 = 2-year college, 1 = 4-year college; (Cooper et al., 2018; Loukas et al., 2018)].

### *Other tobacco use*

Current or past 30-day use of other tobacco products was assessed at wave 4 with an item adapted from the YTS (Starr et al., 2005) and the PATH study (Coleman et al., 2017). The other products assessed included cigars, hookah, and smokeless tobacco. The item asked “On how many days of the past 30 days did you smoke/use [product]?” Use of each tobacco product was scored 0=used on 0 days in the past 30 days or 1=used on 1 or more days in the past 30 days. The scores for all of the three products were summed so that the scores for current use of other tobacco products for each participants ranged from 0-3 (Agarwal et al., 2018).

## *Dependent variables*

### *Current ENDS use and frequency of ENDS use*

Frequency of current ENDS use or past 30-day ENDS use was assessed at wave 6 using an item adapted from the Youth Tobacco Survey (YTS) (Starr et al., 2005) and the PATH

study (Coleman et al., 2017). The item included a description of the range of products under ENDS, including a picture of various ENDS products, followed by asking, “How many of the past 30 days have you used any ENDS product (i.e. an e-cigarette, vape pen, e-hookah, JUUL/pod vape, or mod), even one or two puffs, as intended (i.e. with nicotine cartridges/pods and/or e-liquid/e-juice)?” Participants that indicated they used ENDS on one or more days were categorized as current ENDS users at wave 6 and coded as 1, while those who reported using on zero days were coded as 0.

#### *ENDS nicotine dependence symptoms*

ENDS nicotine dependence was assessed at wave 6 using three items. Two items were adapted from DiFranza and colleagues [(2002); (DiFranza et al., 2002)] and one other item was adapted from Heatherton and colleagues [(1991);(Heatherton et al., 1991)] respectively. The first two items asked ever ENDS users “Have you ever felt like you really needed to use an ENDS product?” (0=no and 1=yes), “Have you ever had a strong craving for an ENDS product?” [0=no and 1=yes; (DiFranza et al., 2002)]. Additionally past 30-day ENDS users at wave 6 were assessed on ENDS nicotine dependence with an additional item adapted from that asked, “How soon after you wake up do you typically use your first ENDS product?” (Heatherton et al., 1991) For the last item, response options included “within 5 minutes of waking,” “6-30 minutes after waking,” “31-60 minutes after waking,” “61 or more minutes after waking,” and “I am not a daily cigarette smoker.” Consistent with other studies (Loukas et al., 2016), for the purposes of this study, the last item was re-coded into a dichotomous variable for the LCA (Nylund-Gibson & Hart, 2014) so that only participants who smoked their first ENDS within 30 minutes of waking were coded “1” and all others were coded as “0,” including non-past 30 day ENDS users. Responses for the three items

were summed and participants with no dependence symptoms were assigned a code of 0 and participants who reported at least one dependence symptoms were assigned a code of 1.

### *Data Analysis*

The purpose of the current study was to examine if membership in the three current ENDS user latent classes predicted subsequent current (i.e., past 30-day) ENDS use, ENDS nicotine dependence symptoms, and frequency of ENDS use one year later. Three separate regressions were run in SPSS version 26 to test hypotheses and predict three separate outcomes at wave 6, which were, current ENDS use at wave 6 (tested with a logistic regression), ENDS nicotine dependence symptoms at wave 6 (tested with a logistic regression), and frequency of ENDS use at wave 6 (tested with a multiple regression). In all regression models, the latent class membership dummy variable served as the independent variable. Socio-demographics of sex, age, race/ethnicity, and college type, and wave 4 past 30-day use of other tobacco products (i.e., cigars, hookah, and smokeless tobacco use) were all included as covariates in the regression models simultaneously. Further, frequency of ENDS use at wave 6 was log transformed as the outcome variable because it was non-normally distributed.

### *Results*

Preliminary analyses indicated that there are changes in current ENDS use across a one year period, from wave 4 to wave 6 among the young adult current ENDS users. As shown in Table 1, all (n=424) participants indicated using ENDS in the past 30 days at wave 4. One year later, at wave 6, only 167 of the 424 participants indicated using ENDS in the past 30 days. However, there did not appear to be any changes in nicotine dependence across the one year period, as 33% of participants indicated having at least one ENDS nicotine dependence symptom at wave

4 compared to 32.1% at wave 6. Lastly, the mean frequency of ENDS use in the past 30 days decreased significantly from wave 4 to wave 6 (see Table 1).

Table 2 shows prevalence of current ENDS use at wave 4 and wave 6 separately by wave 4 class membership. At wave 4, all the participants in the three classes were current ENDS users. Examination of the data indicates that at wave 6, the prevalence of current ENDS use was highest for the high-risk poly tobacco and substance users (n=58; 61.1%), followed by the nicotine dependent ENDS users (n=48; 46.6%), followed by the non-nicotine dependent social ENDS users [(n=61; 27%); see Table 2].

*Table 1. Comparison of the participants' responses to the three outcome variables for the regressions, that is, current ENDS use, ENDS nicotine dependence symptoms, and frequency of ENDS use from waves 4 to 6.*

<b>Outcome variables at wave 6</b>	<b>Wave 4 (n= 424)</b>	<b>Wave 6 (n=424)</b>
Current ENDS use	100%	39.4%
ENDS nicotine dependence symptoms	33%	32.1%
Frequency of ENDS use	M= 8.91** days, SD= 10.32	M=5.13** days, SD=9.77

*Note.* \* $p < .05$ ; \*\* $p \leq .001$  indicate significant findings.

*Table 2. Comparison of the participants' current ENDS use at wave 4 and wave 6 by their latent class membership status.*

<b>Latent Class membership at wave 4</b>	<b>Wave 4 current ENDS use (N=424)</b>	<b>Wave 6 current ENDS use (N=167)</b>
High-risk poly-tobacco and substance users	n= 95 (100%)	n=58 (61.1%)
Nicotine dependent ENDS users	n=103 (100%)	n=48 (46.6%)
Non-nicotine dependent social ENDS users	n=226 (100%)	n=61 (27%)

*Logistic regression results for the model predicting subsequent current/past 30-day ENDS use*

One logistic regression analysis examined the associations between the current ENDS user latent classes at wave 4 and subsequent current ENDS use one year later at wave 6, while controlling for socio-demographics and other current tobacco use covariates. Findings indicated that, compared to the high-risk poly tobacco and substance users, classification in the non-nicotine dependent social ENDS user class predicted significantly lower odds of sustained current ENDS use one year later, after accounting for the socio-demographics and other tobacco use covariates (see Table 3). However, there were no significant differences in the odds of subsequent current ENDS use between the nicotine dependent ENDS users and the high-risk poly-tobacco and substance users. Regarding the socio-demographics and current other tobacco use covariates, only other race and other tobacco use were significant predictors of subsequent current ENDS use. That is compared to whites, identifying as other race also predicted significantly lower odds of sustained current ENDS use one year later. Further, each increase in the number of other tobacco products used (among cigars, hookah, and smokeless tobacco) predicted 1.41 times higher odds of sustained current ENDS use one year later (see Table 3).

Table 3. Role of young adult current ENDS users classes at wave 4 in predicting subsequent current ENDS use at wave 6.

Wave 4 variables	Odds ratio	S.E	95% Confidence interval (lower, upper)
<i>Predictors</i>			
Nicotine dependent ENDS users (vs. high-risk poly-tobacco and substance users)	0.69	0.31	[0.38, 1.26]
Non-nicotine dependent social ENDS users (vs. high-risk poly-tobacco and substance users)	0.28**	0.27	[0.16, 0.47]
<i>Covariates</i>			
18-24 years of age (vs. 25 years and above)	0.89	0.27	[0.52, 1.52]
Male (vs. female)	1.30	0.22	[0.85, 2.00]
<i>Race/Ethnicity</i>			
Hispanic (vs. white)	0.64	0.26	[0.39, 1.06]
Black/African American (vs. white)	1.38	0.50	[0.52, 3.67]
Asian (vs. white)	1.12	0.34	[0.58, 2.18]
Others (vs. White)	0.33*	0.42	[0.15, 0.76]
Four-year college (vs. Two-year college)	0.77	0.38	[0.37, 1.63]
Other tobacco use (scored from 1-3)	1.41*	0.16	[1.03, 1.93]

Note. The high-risk poly tobacco and substance users were coded as 0 and nicotine dependent ENDS users and the non-nicotine dependent social ENDS users were coded as 1. The socio-demographics were coded as 0 = female, 1 = male; 25 years and above=0 and 19-24 years=1; race/ethnicity was dummy-coded with non-Hispanic white as the reference group (coded as 0) and other groups, Hispanic or Latino, black or African American, Asian, and all other race/ethnicity coded as 1 to facilitate comparison of each racial/ethnic minority group against non-Hispanic white participants; 0 = 2-year college, 1 = 4-year college; the scores for current use of other tobacco products for each participants ranged from 0-3. \* $p < .05$ ; \*\* $p \leq .001$  indicate significant findings.

### *Logistic regression results for the model predicting subsequent ENDS nicotine dependence symptoms*

A second logistic regression analysis examined the associations between the current ENDS user classes at wave 4 and subsequent ENDS nicotine dependence symptoms one year later at wave 6, while controlling for socio-demographics and other current tobacco use covariates. Findings indicated that, compared to the high-risk poly tobacco and substance users, classification in the nicotine dependent ENDS user class as well as the non-nicotine dependent social ENDS user class predicted significantly lower odds of ENDS nicotine dependence symptoms one year later, after accounting for socio-demographics and other tobacco use covariates (see Table 4). Regarding the socio-demographics and other current tobacco use covariates, only age and

Hispanic/Latino were significant predictors on subsequent ENDS dependence symptoms. Younger young adults aged 18-24 years and those reporting Hispanic/Latino ethnicity reported significantly lower odds of having ENDS nicotine dependence symptoms one year later, compared to young adults aged 25 years and above and whites (see Table 4).

*Table 4. Role of young adult current ENDS users classes at wave 4 in predicting subsequent ENDS nicotine dependence symptoms at wave 6.*

Wave 4 variables	Odds ratio	S.E	95% Confidence interval (lower, upper)
<i>Predictors</i>			
Nicotine dependent ENDS users (vs. high-risk poly-tobacco and substance users)	0.44*	0.32	[0.24, 0.82]
Non-nicotine dependent social ENDS users (vs. high-risk poly-tobacco and substance users)	0.08**	0.31	[0.05, 0.15]
<i>Covariates</i>			
18-24 years of age (vs. 25 years and above)	0.53*	0.30	[0.30, 0.94]
Male (vs. female)	0.68	0.25	[0.42, 1.11]
<i>Race/Ethnicity</i>			
Hispanic (vs. white)	0.44*	0.29	[0.25, 0.78]
Black/African American (vs. white)	0.63	0.58	[0.20, 1.94]
Asian (vs. white)	0.66	0.39	[0.31, 1.42]
Others (vs. White)	0.56	0.44	[0.24, 1.31]
Four-year college (vs. Two-year college)	0.77	0.42	[0.34, 1.73]
Other tobacco use (scored from 1-3)	1.14	0.18	[0.81, 1.60]

*Note. The high-risk poly tobacco and substance users were coded as 0 and nicotine dependent ENDS users and the non-nicotine dependent social ENDS users were coded as 1. The socio-demographics were coded as 0 = female, 1 = male; 25 years and above=0 and 19-24 years=1; race/ethnicity was dummy-coded with non-Hispanic white as the reference group (coded as 0) and other groups, Hispanic or Latino, black or African American, Asian, and all other race/ethnicity coded as 1 to facilitate comparison of each racial/ethnic minority group against non-Hispanic white participants; 0 = 2-year college, 1 = 4-year college; the scores for current use of other tobacco products for each participant ranged from 0-3. \* $p < .05$ ; \*\* $p \leq .001$  indicate significant findings.*

#### *Multiple regression results for the model predicting subsequent frequency of ENDS use*

A multiple regression model examined the associations between young adult current ENDS user classes at wave 4 and subsequent frequency of ENDS use one year later at wave 6, while controlling for socio-demographics and other current tobacco use covariates. Findings indicated that compared to the high-risk poly-tobacco and substance users, classification in the nicotine dependent ENDS user class as well as the non-nicotine dependent social ENDS

user class predicted significantly lower odds of increase in the frequency of ENDS use one year later [F(10, 413) = 8.47,  $p < .001$ ,  $R^2 = .170$ ] (see Table 5). Regarding the covariates, there was only one significant effect; being Hispanic/Latino predicted significantly lower odds of increase in the frequency of ENDS use one year later compared to whites.

*Table 5. Role of young adult current ENDS users classes at wave 4 in predicting subsequent frequency of ENDS use at wave 6.*

Wave 4 variables	Exp (B)	S.E	95% Confidence interval (lower, upper)
<i>Predictors</i>			
Nicotine dependent ENDS users (vs. high-risk poly-tobacco and substance users)	0.83*	0.07	[-0.33, -0.04]
Non-nicotine dependent social ENDS users (vs. high-risk poly-tobacco and substance users)	0.62**	0.06	[-0.58, -0.35]
<i>Covariates</i>			
18-24 years of age (vs. 25 years and above)	0.97	0.06	[-0.16, 0.09]
Male (vs. female)	1.93	0.05	[-0.03, 0.16]
<i>Race/Ethnicity</i>			
Hispanic (vs. white)	0.88*	0.06	[-0.24, -0.01]
Black/African American (vs. white)	1.11	0.12	[-0.13, 0.33]
Asian (vs. white)	1.04	0.80	[-0.12, 0.20]
Others (vs. White)	0.86	0.09	[-0.32, 0.02]
Four-year college (vs. Two-year college)	1.21	0.09	[-0.15, 0.20]
Other tobacco use (scored from 1-3)	0.99	0.04	[-0.08, 0.06]

*Note. The high-risk poly tobacco and substance users were coded as 0 and nicotine dependent ENDS users and the non-nicotine dependent social ENDS users were coded as 1. The socio-demographics were coded as 0 = female, 1 = male; 25 years and above=0 and 19-24 years=1; race/ethnicity was dummy-coded with non-Hispanic white as the reference group (coded as 0) and other groups, Hispanic or Latino, black or African American, Asian, and all other race/ethnicity coded as 1 to facilitate comparison of each racial/ethnic minority group against non-Hispanic white participants; 0 = 2-year college, 1 = 4-year college; the scores for current use of other tobacco products for each participant ranged from 0-3. \* $p < .05$ ; \*\* $p \leq .001$  indicate significant findings.*

## **Discussion**

Little is known about the role of various ENDS use patterns in subsequent ENDS use among young adults. Findings from this study indicate that although a little more than one third of young adults (39.4%) reported sustained current ENDS use over a one-year period, the majority reported no longer being subsequent current ENDS users, and young adults reported declines in the frequency of ENDS used over the one-year period. These findings are consistent with prior research showing that young adulthood is a period characterized by changes and transitions in

various life domains including tobacco and ENDS use (Agarwal et al., 2018; Arnett & Tanner, 2016; Rath et al., 2012; Stanton et al., 2020). At wave 4, all 424 participants in the three classes were current ENDS users. At wave 6, the prevalence of current ENDS use was highest for the high-risk poly tobacco and substance users (n=58; 61.1%), followed by the nicotine dependent ENDS users (n=48; 46.6%), followed by the non-nicotine dependent social ENDS users (n=61; 27%). Further findings confirmed hypotheses, showing that latent class membership among young adult current ENDS users indeed predicts subsequent current ENDS use, ENDS nicotine dependence symptoms, and frequency of ENDS use over a one-year period. Specifically, findings indicated that membership in the highest risk class of high-risk poly-tobacco and substance users elevated risk for all three outcomes one year later, compared to the lowest risk class of non-nicotine dependent social ENDS users. Further, findings confirmed that membership in the highest risk class of high-risk poly-tobacco and substance users elevated risk for subsequent ENDS nicotine dependence symptoms and frequency of ENDS use one year later, compared to the nicotine dependent ENDS users.

The high-risk poly-tobacco and substance users, which comprised almost a quarter of young adult current ENDS users (22.4%; n=95), had significantly higher odds of sustained current ENDS use one year later compared to the non-nicotine dependent social ENDS users. This class also had significantly higher odds of reporting ENDS nicotine dependence symptoms and higher frequency of ENDS use compared to both the class of nicotine dependent ENDS users as well as the non-nicotine dependent social ENDS users, even after accounting for socio-demographics and current other tobacco use covariates. These findings are consistent with existing evidence that sustained ENDS use is more likely among those who use ENDS more frequently and with those who use cigarettes and other tobacco products compared to their counterparts (Coleman et al.,

2019; Stanton et al., 2020). Findings are also consistent with PBT, according to which young adults who use one class of substance may have increased likelihood of other substances [PBT; (Jessor, 1987; Jessor & Jessor, 1977)]. Given these findings, young adults who are characterized by high-risk poly-tobacco and substance use are an important class to target in comprehensive tobacco control programs.

The nicotine dependent ENDS users also comprised close to a quarter of the current study sample (24.3%; n=103). Nicotine dependent ENDS users had significantly lower odds of prospective ENDS nicotine dependence symptoms and significantly lower frequency of ENDS use, compared to the highest risk class of high-risk poly-tobacco and substance users. However, there were no differences in subsequent current ENDS use between the nicotine dependent ENDS users and the high-risk poly-tobacco and substance users. Thus, this class of ENDS users appear to be at equal risk for sustained ENDS use over time compared to the high-risk poly-tobacco and substance users. There is evidence from existing research that ENDS nicotine dependence is indeed associated with increased use of ENDS among youth as well as adults (Morean et al., 2018; Vogel, Cho, et al., 2020). Given that this class also demonstrated a high probability of ENDS nicotine dependence symptoms at baseline, it is likely that they may sustain ENDS use over time. Taken together, future longitudinal research is needed to understand long-term transition patterns in ENDS use of this class beyond a one-year period.

Finally, results indicate that non-nicotine dependent social ENDS users- the largest class (53.3%; n=226), are significantly less likely than the highest risk class of high-risk poly-tobacco and substance users to report subsequent current ENDS use, subsequent ENDS nicotine dependence symptoms, and more likely to report a lower frequency of ENDS use. Non-nicotine dependent social ENDS users could be experimenting with ENDS given that young adulthood is

a period characterized by experimentation and research indicates that young adults' use of ENDS is not stable (Agarwal et al., 2018; Arnett, 2014; Orlando et al., 2004; Stanton et al., 2020). Two reasons for experimentation among this class could be their social environment, such as peer use, and also their attitudes towards ENDS use. Social ENDS users may be experimenting with ENDS use and learning ENDS use behaviors during their social interactions with peers, according to the Social Cognitive Theory [SCT;(Bandura, 1986)]. In support of the SCT, prior research also indicates that a denser peer network of ENDS users and positive attitudes towards ENDS use predicts subsequent ENDS use among young adults (Agarwal et al., 2018). Thus, it is possible that peer use and attitudes differentiate prospective ENDS use patterns of non-nicotine dependent social ENDS users from the other two classes of current ENDS users, which should be examined in future research. Nonetheless, even if young adults in the non-nicotine dependent social ENDS user class are experimenting with ENDS, this class of current ENDS users is still at risk given the health concerns associated with even low-volume ENDS use, foremost of which is the risk of nicotine dependence from the nicotine in ENDS (Etter et al., 2013) and the negative impact of nicotine on brain development (Yuan et al., 2015). Thus, appropriate tobacco control messaging should be tailored specifically to the non-nicotine dependent social ENDS user class that educates young adults about the harms associated with even occasional ENDS use.

Among the covariates, results indicated that young adults aged 25 years and older, whites and other tobacco users have significantly higher odds of either sustained current ENDS use, ENDS nicotine dependence symptoms, or higher frequency of ENDS use, compared to their counterparts. These findings are consistent with existing research, which emphasize that older young adults aged 25 years and above tend to have riskier ENDS use behaviors and that younger young adults may be still experimenting with ENDS, something that is typical in this

developmental period (Agarwal et al., 2018; Stanton et al., 2020). Findings are also consistent with existing research that whites report heavier tobacco use compared to their counterparts (Scheier & Komarc, 2020) and that young adults who use other tobacco products are more likely to use ENDS (Agarwal et al., 2018; Jessor & Jessor, 1977). It is important to note that each increase in the number of other tobacco products used by young adults, was associated with 1.41 higher odds of sustained ENDS use, which is consistent with the PBT (Jessor & Jessor, 1977), and highlights the importance of considering comorbidity of risky tobacco behaviors among young adult current ENDS users while designing overall tobacco control strategies.

To my knowledge this is the first study to examine if young adult current ENDS user latent class membership predicts subsequent current ENDS use, ENDS nicotine dependence symptoms, and frequency of ENDS use, over a one-year period. Some strengths of the current study are 1) the use of an ethnically/racially diverse sample of young adults from 2-year as well as 4-year colleges, and from multiple cities across Texas, and 2) the use of a prospective design, which allowed determination of temporal precedence between classification in current ENDS user latent classes and prospective ENDS use patterns. However, there are some limitations. First, the findings cannot be generalized to other young adults outside of Texas and therefore future research should replicate the study with broader, nationally representative samples to further understand the transitions in ENDS use behaviors. Another limitation is that the study utilized data over a one-year period (two time points), and given that young adulthood is a period characterized by transitions in tobacco use (Arnett & Tanner, 2016; Rath et al., 2012), longitudinal research spanning more than one year should be conducted to understand these transition patterns over a longer period of time. Finally, given that there are a number of different types of ENDS products, such as the early-generation cigalikes to more recently evolved modifiable ENDS, and even more recently introduced vape

Pods (Barrington-Trimis et al., 2018; Huang et al., 2019), there may be differences in prospective ENDS use patterns based on use of different device types. Thus, future research should examine if and how device type predicts subsequent ENDS use patterns among young adults.

Taken together, findings from this study extend the existing research on young adult ENDS use by examining the role of various patterns of ENDS use in subsequent ENDS use behaviors. The current study helps inform tailored interventions and tobacco control messaging for young adults. For instance, tailoring messaging regarding the risk for sustained use of ENDS, prospective ENDS nicotine dependence symptoms, the risk of higher frequency of ENDS use, especially towards young adults aged 25 years and above, whites, and other tobacco users, could help with reducing the tobacco related burden among the high-risk poly-tobacco and substance users. Further, tobacco control interventions tailored to the high-risk poly-tobacco and substance users could include preventive messaging on comorbid behaviors such as cigarette use, alcohol use, and marijuana use. Thus, while existing research demonstrates the need to tailor tobacco control messaging for different groups of young adult tobacco users (Boynton et al., 2016), the current findings also suggest that these should specifically be tailored to the nicotine-dependent ENDS users and the high-risk poly-tobacco and substance users. In summary, results underscore the role of current ENDS user latent class membership in prospective ENDS use patterns and the need for development of distinct tobacco control messaging and intervention strategies tailored to different sub-groups of young adult ENDS users.

## **Chapter 6: Conclusion**

This dissertation aimed to expand the knowledge around young adults' current ENDS use patterns and their role in subsequent ENDS use behaviors, using a person-centered approach and prospective design. This dissertation filled gaps in the existing literature where most studies are limited to examining ENDS dichotomously as use/non-use and using only variable centered approaches that limit the examination of heterogeneity in behaviors (Amato et al., 2016; Coleman et al., 2019; Stanton et al., 2020). The two studies together empirically identified three young adult current ENDS user latent classes, their common characteristics, and their roles in subsequent ENDS use over time.

Although attention has been given to identifying patterns of cigarette use, very little research has focused on patterns of ENDS use among young adults, and has just begun to scratch the surface on patterns of ENDS use among all adults (Amato et al., 2016). Study 1 is the first to identify current ENDS user latent classes and their common characteristics among a cohort of young adults in Texas. Study 1 identified three distinct latent classes of young adult current ENDS users, which are, non-nicotine dependent social ENDS users, high-risk poly-tobacco and substance users, and nicotine dependent ENDS users. A Latent Class Analysis (LCA) approach was used to identify the prevalence of the three classes and determine socio-demographic and other tobacco use correlates. Findings confirmed the limited existing research indicating that ENDS users are not a homogenous group (Amato et al., 2016), and extended our understanding of the different ENDS use behaviors among young adult current ENDS users.

Contrary to initial expectations that there would emerge at least four distinct classes of young adult current ENDS users, including two classes of addicted (social and non-social) ENDS users and two classes of non-addicted (social and non-social) ENDS users, there were three classes

that emerged. The classes that emerged were- non-nicotine dependent social ENDS users, high-risk poly-tobacco and substance users, and nicotine dependent ENDS users. In partial agreement with the initial expectations, findings revealed two distinct classes of addicted current ENDS users that both had a high probability of ENDS nicotine dependence symptoms and a high probability of using ENDS more frequently (that is, 6 days or more in the past 30 days), indicating that there exists multiple risky ENDS use behaviors, something that existing research had not explored yet. Thus, appropriate messaging tailored towards the high-risk poly-tobacco and substance users and the nicotine-dependent ENDS users that educates them about ENDS nicotine dependence and frequency of ENDS use, is warranted. Additionally, the high-risk poly-tobacco and substance user class provides evidence for comorbidity of risky behaviors (such as cigarettes, binge alcohol use, and marijuana use) among a sub-group of young adult current ENDS users, which also call for tailored messaging and initiatives that focus on co-occurring behaviors. Further, the non-nicotine dependent social ENDS users also need to be educated on health concerns associated with even low-volume ENDS use such as the risk of nicotine dependence (Etter et al., 2013) and the role of nicotine in brain development (Yuan et al., 2015), in order to limit ENDS use among this class.

Apart from understanding different classes of ENDS users, results from Study 1 also help in the development of distinct tobacco control intervention strategies tailored to different classes of young adult ENDS users. For instance, tailoring messaging regarding the risk for persistent use of ENDS especially among older young adults aged 25 years and above could help with reducing the tobacco related burden among the nicotine dependent ENDS user class. Similarly, tobacco control interventions tailored for the high-risk poly-tobacco and substance users should also include messaging on alcohol and marijuana use, especially tailored towards males and other

tobacco users in order to mitigate the tobacco related burden among the high-risk poly-tobacco and substance users.

Despite the strengths of Study 1, foremost of which are the use of a diverse sample of young adults from multiple cities across Texas and the use of LCA in understanding classes of young adult current ENDS users, there were some limitations and recommendations for future research. One limitation of the study was that the indicator variables were dichotomized for the LCA (Nylund-Gibson & Hart, 2014) given the limited sample size to maximize power for the analysis. Future research should replicate the findings with larger samples that enable use of Latent Profile Analysis, which uses categorical indicator variables, to further understand the characteristic breakdown of the classes. Another limitation is that the study utilized data from one time point to understand current ENDS user classes, and longitudinal research is needed to understand transition patterns of the three identified classes to determine which classes are experimenting with ENDS and which ones sustain ENDS use over time. Longitudinal research examining these transition patterns is especially important given that young adulthood is a period characterized by numerous transitions including in tobacco use behaviors (Arnett & Tanner, 2016; Orlando et al., 2004; Rath et al., 2012). Another limitation is that the study sample was comprised of only young adult current ENDS users since self-identifying as a social ENDS user (a very important indicator for the LCA analysis), was assessed only of current ENDS users. It is possible that self-identifying as a social ENDS user may be a better indicator in differentiating latent classes among ever ENDS users that include current ENDS users. This is because existing research on cigarettes has found that self-identifying as a social smoker distinctly drives latent class formation among a sample that includes diverse categories of smokers, including non-smokers and current smokers (Villanti et al., 2017).

Study 2 of this dissertation built on Study 1 and specifically identified the role of young adult current ENDS user classes in predicting ENDS use behaviors. Results found that the high-risk poly-tobacco and substance users and the nicotine dependent ENDS users are at elevated risk of sustaining ENDS use. Membership in the highest risk class of high-risk poly-tobacco and substance users also predicted higher odds of ENDS nicotine dependence symptoms and higher frequency of ENDS use one year later, compared to the non-nicotine dependent social ENDS users and the nicotine dependent ENDS users. Results from Study 2 indicated that ENDS use was not stable across time and in fact, more young adult current ENDS users reported not using ENDS one year later than those who reported sustaining current ENDS use (39.4%), which is consistent with existing research (Coleman et al., 2019; Stanton et al., 2020). Similarly, findings showed that the frequency of ENDS used also declined after one year. These findings are consistent with limited research showing that a substantial proportion of young adults stop using ENDS one year later (Stanton et al., 2020) and point to the existing evidence that young adults may “mature” out of ENDS use as they get older (Loukas et al., 2019). Thus, longitudinal research that expand on Study 2 by tracking ENDS use trajectories longer than a one-year period are needed to understand the role of young adult latent classes in subsequent long-term ENDS use.

Results from Study 2 are important from a public health perspective because they highlight that tobacco control messaging and interventions should be tailored towards the nicotine dependent ENDS users and the high-risk poly-tobacco and substance users. Specifically, high-risk poly-tobacco and substance users may be at the highest risk of sustained ENDS use behaviors given that they have significantly higher odds of subsequent ENDS use, and/or ENDS nicotine dependence symptoms, and/or higher frequency of ENDS use (Coleman et al., 2019; Morean et al., 2018; Stanton et al., 2020; Vogel, Ramo, et al., 2020), compared to the non-nicotine dependent social

ENDS users. Therefore to mitigate harm among high-risk poly-tobacco and substance users, tailoring messaging regarding the risk for sustained use of ENDS, especially towards young adults aged 25 years and above, whites, and other tobacco users, could help with reducing the tobacco related burden among the high-risk poly-tobacco and substance users. Further, tobacco control interventions targeted at this class should include preventive messaging on comorbid behaviors such as cigarette use, and alcohol and marijuana use.

To my knowledge Study 2 is the first study to examine if latent class membership predicted subsequent current ENDS use, frequency of ENDS use, and ENDS nicotine dependence symptoms one year later. Despite the strengths of the current study, foremost of which are the racially/ethnically diverse sample of young adults from 24 (2-year and 4-year) colleges across multiple cities in Texas and the use of prospective design, there are some limitations and recommendations for future research. One limitation is that the study utilized data over a one-year period (two time points), and longitudinal research spanning more than a year is needed to understand trajectories in ENDS use over a longer period of time. This is especially true given that there are changes in ENDS use across young adulthood (Agarwal et al., 2018; Stanton et al., 2020). Another limitation is that I could not conduct Latent Transition Analysis (LTA) to understand changes in the latent classes across time. That is because, only current ENDS users at waves 4 & 6 were assessed on self-identifying as a social ENDS user (a very important indicator for the LCA analysis). Because of that, 60.6% out of the 100% of current ENDS users at wave 4 indicated non-current use at wave 6, which resulted in a lot of missing data on the current ENDS use variable as well as the self-identifying as a social ENDS user indicator variable to successfully conduct the LTA at wave 6. One way to potentially conduct a successful LTA in future work would be to use ever ENDS users as the sample and assess those ever ENDS users on the indicator variables for

the LCA as well as the LTA. Future research should also examine differences in prospective ENDS use based on use of different ENDS device types, given the myriad of ENDS products available on the market (Barrington-Trimis et al., 2018; Huang et al., 2019). For instance, there is evidence that newer generation vape pods contain high nicotine concentrations ranging from 21.8 mg/mL to 56.2mg/mL (Goniewicz et al., 2019), which may mean that young adults in the different latent classes using vape pods may be at elevated risk of sustained ENDS use from the high nicotine in these products.

Findings from the two studies in this dissertation together reiterate that young adulthood is a developmental period associated with risky behaviors such as ENDS use, binge alcohol use, marijuana use, and cigarette use (McMillen et al., 2014; Rath et al., 2012; Villanti et al., 2017), making it a critical period for prevention and intervention efforts. Findings also highlight the heterogeneous nature of ENDS use (Amato et al., 2016), by identifying distinct classes of users, some of whom are more likely to continue to use ENDS and develop dependence symptoms, whereas others are likely to desist use. Given these findings, tobacco control messaging and interventions need to be tailored to address multiple tobacco and substance use patterns across a spectrum of use behaviors and substances such as ENDS use, alcohol use, marijuana use, and cigarette use.

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