2017

Socioecological Aspects of Tobacco Use in College Populations

Michael D. Sawdey
Virginia Commonwealth University

Socioecological Aspects of Tobacco Use in College Populations

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University

by

Michael D. Sawdey

Bachelor of Science, Health Science, San Diego State University, 2010
Master of Public Health, Epidemiology, San Diego State University, 2012

Director: **Elizabeth Prom-Wormley, Ph.D.**
Assistant Professor
Division of Epidemiology, Department of Family Medicine and Population Health

Virginia Commonwealth University
Richmond, Virginia
May, 2017

Acknowledgement

The author wishes to thank several people. I would like to thank Dr. Elizabeth Prom-Wormley for her invaluable guidance and constant moral support over the years as my advisor and in the completion of this project. I would also like to sincerely thank the members of my committee, Dr. Thomas Eissenberg, Dr. Alison Breland, Dr. Linda Hancock, and Dr. Steven Cohen for their commitments toward this project and their unwavering support. I would also like to acknowledge the Division of Epidemiology and the Center for Study of Tobacco Products at VCU. Finally, I would like to thank my wife, Brianna, my parents, and our family for their love and support.

Table of Contents

List of Tables and Figures

Abstract

SOCIOECOLOGICAL ASPECTS OF TOBACCO USE IN COLLEGE STUDENTS

By Michael D. Sawdey, MPH, Ph.D.

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University

Virginia Commonwealth University, 2017

Director: Elizabeth Prom-Wormley, Ph.D.
Assistant Professor
Division of Epidemiology, Department of Family Medicine and Population Health

Background: Although cigarette smoking is decreasing in the US and among college students, tobacco use remains a major public health problem. Specific socioecological gaps in the literature related to college tobacco use exist including: trends of tobacco use, combinations of polysubstance use, and availability of tobacco products around college campuses.

Objectives: The main goal of this research was the understand interrelationships that exist within a socioecological framework of college tobacco use. Specifically, this project aims to: 1) examine trends of tobacco and polytobacco use by gender and associations of polytobacco use and perceived peer tobacco use, 2) examine specific combinations of polysubstance use and how the resulting profiles of use differ by gender, and 3) evaluate tobacco retailer density around college campuses and in neighborhoods of Richmond, VA.

Methods: Two chapters of this project use data from the National College Health Assessment II from 2008-2015. The third chapter uses data collected from electronic cigarette brand websites to geospatially examine tobacco retailers in the Richmond Virginia Metropolitan Statistical Area. Various statistical analyses were utilized to complete each project including linear, logistic, and negative binomial regression, latent class and confirmatory factor analysis, and spatial analysis.

Results: Trends of some tobacco products among US college students declined while others remained stable from 2008-2015. Nearly 1 in 4 college students used a tobacco product and nearly 1 in 10 were polytobacco users. Alcohol and marijuana use remained stable. Specific classes of polysubstance users were found to exist between males and females, in addition to sociodemographic and institutional associations with polysubstance use by gender. College campuses in the Richmond area were found to have a substantial number of tobacco retailers and retailer density was higher in low socioeconomic status neighborhoods.

Conclusions: The findings from the three different studies fill extensive gaps in the literature related to trends of college tobacco use, differences in classes of polyuse by gender, and availability of tobacco around college campuses. Overall, while tobacco use is declining, there are still a substantial proportion of college students who use tobacco and other substances and products appear to be readily available.

Chapter 1: Background

Tobacco Use

Tobacco use remains the leading cause of preventable disease and death in the United States (US), despite half-a-century of decreasing use [1]. Tobacco is the only consumer product that kills up to half of its users [2] while affecting nearly every human organ [3]. Long-term use has demonstrated that the life expectancy of a smoker is nearly ten years less than that of a non-smoker [4,5], contributing significantly to lost productivity and health care costs of tobacco-associated diseases. The risks associated with tobacco use have been addressed with prevention efforts such as educational campaigns (mass media campaigns and message targeting), interventions (community, family, school-based, etc.), and policy/regulation efforts that have contributed to declining smoking rates from 42% of adults in 1965 to 17% in 2014 [1]. From a public health perspective, the best method for addressing population tobacco use continues to be prevention of youth and young adult initiation in addition to development of novel means of understanding and addressing persistent use [1,6].

While rates of overall tobacco use are decreasing, individuals continue to initiate and sustained users continue to use tobacco in various forms due to the addictive nature of the product [1]. In spite of the potential harms of use, which are often known to the user, multiple factors influence initiation and continued use of tobacco. The 2012 Surgeon General's Report, *Preventing Tobacco Use Among Youth and Young Adults*, specifically describes influences of use as "multi-dimensional" and "interrelated" [7]. These factors are best defined as "overlapping combinations of biological, psychosocial, and environmental influences" that determine the overall risk profile for an individual through protective and risk factors [7]. The progression of these influences often has generational effects requiring continued research, where each

generation is confronted with new products, forms of use, and social and environmental factors requiring novel research to continue effective prevention.

The most recent estimate of current cigarette use from the 2014 National Youth Tobacco Survey (NYTS) demonstrates that 9.2% of high school students used in the last 30 days [6]. This is the lowest estimate ever obtained from the NYTS since the inception of the survey in 1998, when it was reported that 29% were current cigarette smokers. Youth prevention is particularly important as nearly 90% of smokers start prior to the age of 18 [7]. Continuation of these prevention efforts into young adulthood are equally important; of those who do not start before the age of 18, nearly all start before the age of 26 [7]. College students are a unique population of young adults (age 18-24) that are significantly vulnerable to new tobacco products and behaviors, shifting perceptions and social norms and use, and expanding availability [8]. The college time-period also provides a potentially valuable setting to promote education and provide treatment of tobacco behaviors [9]. This dissertation will focus on various influences and behaviors of tobacco use in the college setting including: availability, perceptions, and various aspects of tobacco behaviors.

Tobacco Use among College Students

As of 2011, approximately 10% of college campuses nationwide were smoke-free increasing to 33% in 2016 [10]. This change demonstrates renewed efforts in tobacco policy for prevention in this group. Tobacco use among college students traditionally has been similar to non-college young adults with cigarettes being the primary form of use. Prevalence rates of use for college students vary widely with 17-25% being previous month cigarette smokers [11,12]. Additionally, new/alternative products such as hookah, electronic cigarettes (e-cigarettes), and small cigars have become extremely popular with college students and young adults [13].

Alternative tobacco products are viewed as more socially acceptable, less harmful, and less addictive than cigarettes [13], however use of these products could lead to tobacco addiction and cigarette use [14,15]. Addressing tobacco use among college students is important for several reasons. First, college smokers who smoke either daily or occasionally often smoke throughout college and continue after graduation into adulthood [16,17]. Second, college smokers and tobacco users are more likely to experience depression [18], mental health problems[19], and generally have worse health outcomes during and after college [20]. Preventing uptake of tobacco and providing cessation services to these students would help mitigate long term physical and mental health issues. Lastly, nearly all progression from occasional to daily smoking occurs by age 26 [7].

Students are particularly vulnerable to new forms of tobacco use such as hookah, e-cigarettes, and cigars. These products have become popular with students and also have become commonly used in tobacco initiation behaviors [21,22]. A recent study found that while cigarettes were the first product tried among half of student respondents (50.5%), hookah (24.2%) and emerging tobacco products like e-cigarettes or snus (15.1%) were used by the remaining initiators [21]. Additionally, alcohol and marijuana use are common substances that are often used in college populations that are associated with tobacco use[23].

Alcohol, Marijuana, and Other Substance Use in College Students

Alcohol and marijuana use are common in college populations. Past 30-day use of alcohol among college students is much higher than their non-college counterparts (63 vs. 56%) and however, non-college young adults often have higher rates of marijuana use (21 vs. 26%) [11]. Additionally, rates of alcohol use have stayed relatively consistent over the last 10 years, while rates of marijuana use have increased, particularly among college students versus non-college young adults [11]. Additionally, drug use other than marijuana is reported in nearly 1 out of every 5

college students annually with rates of past 30 day use varying by substance [11]. More attention has also been given to binge drinking, as from a risk perspective, college student binge-drinkers are at much higher odds of negative health outcomes such as sexual consequences, substance use, and mental health issues, than those not binge drinking [24,25]. Alcohol, marijuana, and other substance use behaviors, including tobacco, often do not occur in isolation defining users as multi-product users.

Multiple-Product and Non-Daily Tobacco use in College Students

Multiple-product use and non-daily use are two phenomena that have become common for college tobacco users [22,26]. Multiple-product use can be broken into two types of use: dual- or poly- use. Dual-use is defined as the use of for two tobacco products (or substances) concurrently, while poly-use is use of more than two tobacco products (or substances) concurrently in the last 30 days. Multiple-product use often consists of various combinations substances used, depending on the individual [21]. Multiple-product use is associated with increased risks for physical and psychological health outcomes compared to single-product use [27] and is known to increase effects related to morbidity and mortality over the long-term [7]. Additionally, nicotine dependence may be worse in dual- or poly-users as they show signs of withdrawal symptoms more frequently than single-product users [27,28]. Approximately 15% of college students are current polytobacco users, which is lower than other young adult populations [29]. Furthermore, research examining poly-use is lacking as many studies only examine associations with single-products or substances. Assessment of multiple-product use and describing characteristics that make up specific types or groups of multiple-product users could be a valuable precursor to providing cessation services and salient intervention messaging for those people who use multiple tobacco products.

Multiple product users commonly are also non-daily users; however non-daily users are not exclusively multiple product users. Non-daily users are users who report using any tobacco product less frequently than every day in the previous month [30]. More than half of non-daily and social cigarette smokers report smoking less than six days out of the last 30 [30], however many college interventions and prevention efforts are only directed toward heavy or daily users[9]. Use of waterpipe or hookah has been a part of social situations for college students since it gained popularity, where use only occurs a few times a month [31]. All forms of social tobacco use are associated with lower frequency, rates of use, and less nicotine dependence compared to daily users, yet social users often have less intention to quit and fewer attempts [32]. Social users perceived themselves as smoking or using exclusively in the social environment, which over time becomes less true[32]. However, social users appear to not be as susceptible to the same tobacco-related health risks as daily users [33].

Differences in multiple product and non-daily use also varies by gender. Studies assessing single- and multiple-behavior tobacco use often control for the effects of gender or examine use of men or women only, but do not often assess gender in cross-sectional or longitudinal studies, separately. While gender is reported as being associated with substance use or adjusted for within other association models, very few studies examine gender differences in college tobacco use, which could be an important factor for designing prevention, intervention, and treatment. College male students generally have higher prevalence and frequency of use rates of cigarettes and cigars and often have greater nicotine dependence, leading to heavier use [11,34], whereas college females have higher rates of hookah/waterpipe use [35]. Continued examination of these behaviors is imperative as rates of use between males and females change over time due to personal, social, and environmental influences such as of generational cohort

effects of use, shifting social norms/perceptions, emerging alternative products, and expanding availability of products [11].

A Socioecological Model for Tobacco Control in College Students

The 2012 Surgeon General's Report, *Preventing Tobacco Use Among Youth and Young Adults: A Report of the Surgeon General* outlines a model for the influence of tobacco use among youth and young adult populations [7]. This model defines specific social, environmental, cognitive, and genetic influence on the use of tobacco through the Theory of Triadic Influence (TTI) [36]. The socioecological model builds on the TTI by providing a conceptual framework though factors that are known to be important to tobacco prevention: policy/regulation, community environment, personal environment, and personal choice/behaviors [37,38]. Figure 1.1 provides an adapted socioecological model for this dissertation. Based on the adapted model, a hierarchy is established from left to right moving from policy, regulation, and laws to sociodemographic/economic factors influencing the overall community environment. The community environment in turn influences both personal and institutional environments which influence behaviors. Within each factor are specific aspects that together comprise the factor. These aspects are meant to be measurable as the factors are often latent in their nature and therefore immeasurable.

Using the socioecological model as an approach, this dissertation seeks to address specific aspects of three factors addressing the community environment, personal/institutional environment, and tobacco behaviors among college students. To accomplish this, three studies will be completed. Study one will assess trends overtime of tobacco behaviors, in addition to frequency of use and perceptions using a national data sets. The second study will assess profiles of polysubstance use behavior groups by gender and frequency of use. The third and final study

will examine tobacco and e-cigarette availability in relation to a single community's colleges/universities, and neighborhood socioeconomic status. These three studies will provide insight and clarification as to why these behaviors remain persistent within the college environment. All three studies contribute to the literature on tobacco use (and in addition, marijuana and alcohol use) among college students by: 1) providing an understanding to characteristics and reasons for changes in use across a college population; 2) informing prevention, treatment, and intervention efforts directed at college students; and 3) helping to inform policy and regulation.

The specific aims of this proposal were:

Aim 1: Assess the trends of tobacco, marijuana, and alcohol use, in addition to perceived peer use among US college students by gender.

Hypotheses: Trends of college tobacco, alcohol and marijuana use will follow national trends of the general population, but rates and trends will differ by gender.

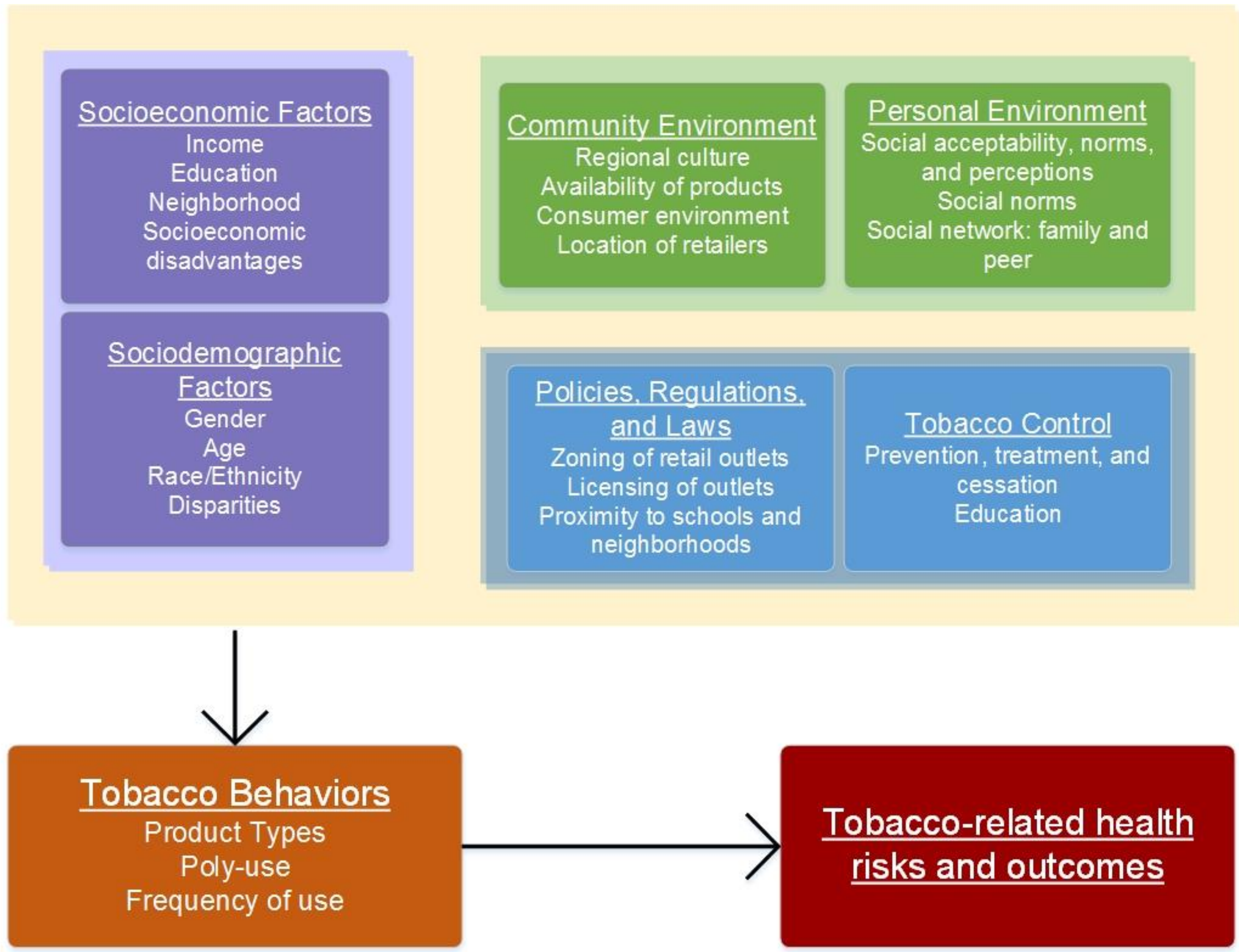
Aim 2: Examine profiles of polysubstance use behaviors (tobacco, alcohol, and marijuana) among college students by gender and frequency of use.

Hypotheses: Specific profiles of college polysubstance use will exist by gender.

Aim 3: Assess the geographic distribution of tobacco/e-cigarette retailers in the Richmond Metropolitan Statistical Area (MSA) surrounding college campuses and in relation to socioeconomic status (SES).

Hypotheses: Colleges will have a large number of tobacco/e-cigarette retailers surrounding campuses and tobacco/e-cigarette retail density will be higher in lower SES areas.

Figure 1.1. Socioecological model of Tobacco use in College Students



Chapter 2: Trends of Tobacco and Polytobacco use and Associations with Perceived Peer Tobacco use

ABTRACT

Background: Many studies focusing on college tobacco use often examine a single tobacco behavior type, data that is older than five years, or populations that may not be generalizable to the national college population. Patterns of college tobacco use are changing due to the introduction and increasing popularity of alternative products and shifts toward non-daily use. New-to-market and alternative tobacco products such as hookah, e-cigarettes, and smokeless tobacco are increasingly becoming the first product tried in college populations and use of these products, increases likelihood of all tobacco use. Polytobacco use or concurrent use of two or more tobacco products in college populations varies by males and females, however little research exists examining trends. Additionally, associations between specific student characteristics and perceptions of peer use with types of polytobacco use may exist between genders.

Objective: Examine trends of tobacco and polytobacco use by gender and associations with perceived peer use and student characteristics.

Methods: Data were obtained from the National College Health Assessment II from Fall 2008 to Fall 2015 on tobacco (cigarettes, hookah, cigars, smokeless tobacco, and e-cigarettes), alcohol, and marijuana use. Across the seven academic years, trends of single-product, polytobacco (two or more), and perceived peer use were examined using descriptive statistics and simple linear regression. Multivariate logistic regression was performed to assess associations of polytobacco use with specific tobacco products including perception of peer use and demographic and institutional characteristics.

Results: Tobacco and polytobacco use over the study period demonstrated declines for cigarettes, hookah, and cigars. Males overall had greater declines in tobacco use, but consistently had higher rates for single-product and polytobacco use compared to females. Approximately 8% were polytobacco users (11% males, 4% females) with cigarettes being the most used tobacco product among polyusers. Polytobacco use with each product showed significant and strong associations for alcohol and marijuana use, in addition to living off campus, participating in a Greek organization, being white, and perceiving peer tobacco use.

Conclusions: While tobacco and polytobacco use declined across the study period, there were significant differences in use between males and females. Furthermore, nearly 10% of college students took part in polytobacco use. While use of any tobacco products increases risk of negative health outcomes, the rate of polytobacco use in this study may suggest that aggressive efforts need to be taken to address multiple product use and that these efforts may need to be tailored differently for males and females. College students may continue to "diversify" their tobacco use with new and alternative products available.

INTRODUCTION

Background

Rates of cigarettes, marijuana, and alcohol use among college students have remained stable or showed little change over the last decade [11]. However, the overall pattern of tobacco use in has changed due to the increasing popularity of alternative tobacco products (such as hookah, electronic cigarettes (e-cigarettes), cigars, and smokeless tobacco), increasing tobacco availability around colleges [39], changing patterns of use [30], and changing social norms and perceptions of use [13]. However, little to no research has examined trends of single-product and polytobacco use of cigarettes, hookah, cigars, smokeless, and e-cigarettes in relation to perceptions of peer tobacco use in college populations.

Prevalence of Tobacco Use in College Populations

While the use of cigarettes in college populations has decreased over the last decade [11], this decline is offset by the increasing use of alternative tobacco products and shifting patterns of cigarette use [40]. The prevalence of daily cigarette use in college populations has dropped from 17% to 5% over the last decade, although past 30-day use is approximately 13 to 15% [11,41]. The overall decrease in daily cigarette use is offset by the use of hookah/waterpipe, cigars, smokeless tobacco, and electronic cigarettes, which account for a substantial proportion of tobacco use in college populations [11]. Nearly one-third of college students start with an alternative product and these non-cigarette initiators are still at risk of moving to cigarette use [22]. Similar to cigarettes, cigars, smokeless tobacco, and e-cigarettes are known to be used weekly or daily [26], whereas hookah is often used a few times a month [4]. While use of alternative products have increased overall, alternative product use is known to be associated with specific subgroups [26,42,43].

Additionally, nondaily cigarette use (use less than daily) has surpassed daily use as it is estimated that among all college cigarette smokers nearly 70% are nondaily users [30].

Recent research estimates of current past 30-day waterpipe use among college students is between 8-15%, with 30% of students having lifetime use of hookah [44,45]. Another study, using *Monitoring the Future* data, found that 19% had used a waterpipe, with 7% "sustaining use", defined as using at least six occasions in the past 12 months [46]. The differences in use rates reflect the difficulty in hookah/waterpipe surveillance due to non-frequent use. However, any hookah use is still concerning due to the health effects [47] as use sessions are often 45 minutes or more longer among college users [48].

Among all age groups, cigar use is most common among young adult users with approximately 12% using in the last 30 days [42]. Prevalence rates of cigar use have remained consistent over the last decade [26]. However, certain populations may engage in their use more frequently. For example, use of cigars, little cigars, and other variations are most common among racial minority groups, particularly among black college students [42]. Most college and young adult cigar users are nondaily cigar users, which is consistent with trends of cigarette smoking [42].

Among non-tobacco substance use in college populations, marijuana and alcohol use remain high [23,29,40]. Marijuana use overall is on the rise among college populations with 21% reporting past 30-day users [11,49]. Trends of past 30-day use peaked in 2000 at 20%, dropping until 2008 to 17%, and then increasing to current levels. The recent increases in marijuana use could be influenced by the legalization of marijuana [49], changing perceptions and acceptability [13], and the increase in alternative marijuana products [50] such as vaporizers or edibles [51]. The adverse health effects of marijuana use are not well researched however, marijuana is known to be addictive, cause abnormal brain development in youth, lead to progression of other substance

use, and cause lung issues like chronic bronchitis [52]. Alcohol use has continued to be a problem on college campuses, especially for individuals taking part in excessive or binge drinking [11]. Previous 30-day use has declined over the last five years from 65% to 63%, however daily use has remained the same at approximately 4% [11]. Binge drinking, often defined as four or five drinks in one sitting over the last two weeks, has slightly decreased in the last decade from 40% to 35% [11], but remains a high-risk behavior and predictor of other substance use in college populations [53,54].

Gender Differences in Tobacco and Substance Use in College Populations

Overall, males take part in more tobacco, marijuana, and alcohol use than females [11]. The *Monitoring the Future* study examines gender differences in prevalence of use among young adults in college [11]. MTF reports that males use cigarettes more frequently compared to females [11]. Additionally, males are more likely to be daily users and continue use after college than females [11]. Use of cigarettes among males and females has continued to decline with 16% of males and 9% of females being smokers. Among alternative tobacco products, males generally have a higher prevalence of cigar, cigarillo, small cigar, e-cigarette, and smokeless tobacco use [35,55,56]. Rates of current cigar and e-cigarette use are higher in males (cigars: 9%, e-cigarettes: 14%) than females (cigars: 3%, e-cigarettes: 6%) [11].

Males have a considerably higher prevalence of marijuana use than females [11]. Additionally, male college students tend to take part in more frequent marijuana and alcohol use behaviors and are more prone to severe health risks and consequences based on their use patterns [18,57,58]. The overall increase seen in marijuana use among college students has primarily been attributed to females taking part in marijuana use as the trend of male marijuana use has remained stable [59,60]. In addition to marijuana, males also have higher rates of alcohol and binge

drinking than females [11]. Alcohol use in college populations overall has continued to slightly decrease, however males report higher rates of daily drinking and binge drinking [11]. For nearly all substances, the use alcohol, particularly binge drinking, strongly predicts the use of tobacco or marijuana use in college populations [4,20,43,61,62]. Therefore, in most college students, tobacco, alcohol, and marijuana behaviors are not occurring independently [23,53].

Polytobacco and Polysubstance (Tobacco, Alcohol, and Marijuana) Use in College Populations

Polysubstance use, or concurrent use of substances within a time period has become more common in college populations [63] and more research is needed to understand the patterns of use or co-use in college populations. Recently, more attention has been given to examining polysubstance use by assessing and defining the substances that commonly are used together by college students [23,53]. These studies attempt to classify users into groups based on patterns of past use. The onset of polysubstance use is related to social behaviors, shifting patterns of product use, perceptions of social norms, and the introduction of new behaviors such as alternative tobacco, alcohol, and marijuana products [21,46,63]. Although cigarette users are more likely to be users of other tobacco products, alternative tobacco users may not use cigarettes [22,64]. To help clarify the poly-use issue in college populations, examining trends in combinations of behaviors may provide needed evidence for future interventions to most effectively target specific behaviors or individuals on college campuses. Further, trends of polyuse by gender is needed as it is currently an understudied area of substance use.

Perceptions of Peer Tobacco, Alcohol, and Marijuana Use in College Populations

Perceptions of use including social norms, knowledge, attitudes, and beliefs play an important role in tobacco, alcohol, and marijuana use in college populations [9,65]. Previous work has demonstrated that assessment of perceived peer use of tobacco products can serve as an indicator of the overall social norm [66]. Additionally, the associations between each product and perception of peer use for each product differ by product [66]. To our knowledge, the relationships between perceived peer use and polytobacco use have not been assessed.

Collectively, social use and perception of the social norms, play a primary role in the use of individual substances. For example, individuals characterizing themselves as “social users” often have peers that do the same and believe that use in this context does not constitute being an actual “user” [67,68]. Specifically, a tobacco “user” is conceptualized as an individual with yellowing teeth, who purchases products for self-use, and uses beyond weekends and in social situations [67]. Little is known however about the influence of perception of peer tobacco and substance use and polytobacco and polysubstance use. In particular, how changes in perceiving peer substance use over time, influences single and polytobacco (or polysubstance) behaviors. Further, no known study to date has examined these differences between male and female subgroups. Due to the increasing use of alternative tobacco products, shifting frequency of use, and lack of research regarding trends of perceived peer use, the tobacco landscape among college populations continues to change. Thus, the purpose of this study is to examine trends and relationships in college student single-product tobacco use, polytobacco use, and the perception of peer use over time by gender. The goal of this study is to provide a comprehensive examination into current and lifetime use of tobacco behaviors, describe polytobacco use, and to describe the relationship between polytobacco use and perception of peer use.

METHODS

Data source

This study utilizes de-identified data from 15 cross-sectional surveys of the National College Health Assessment II (NCHA II) sponsored by the American College Health Association. The NCHA II survey are administered biannually in the Fall and Spring semesters beginning in Fall 2008. For this study, the utilized data was collected biannually (Fall and Spring semesters) between Fall 2008 and Fall 2015 and were aggregated into data sets of seven academic years (Fall and Spring semesters from 2008-2014) and one additional Fall semester (Fall 2015). Between 30 and 130 institutions participate in any given semester, with the majority administering the survey in Spring, resulting in significantly higher respondent samples for Spring resulting in the academic year aggregation. The survey is administered as a web- or paper- based questionnaire consisting of ~100 questions related to tobacco and substance use, physical and mental health, sexual health, and demographics among other areas. Individual institutions obtain Institutional Review Board (IRB) approval prior to administering the survey. After obtaining IRB approval from each participating institution [69], paper questionnaires were administered in randomly selected classrooms whereas invitations to participate in the web-based questionnaire were sent to randomly selected students [70]. IRB approval for this study was obtained from Virginia Commonwealth University IRB and deemed exempt. For institutions to participate in the NCHA II survey, students must be randomly selected and invited to participate in the web survey or be in randomly selected classrooms for the paper survey. Many of the question formats used in the NCHA II survey are adapted from other national college health surveys such as the National College Health Risk Behavior Survey, Harvard School of Public Health 1999 College Alcohol Study, and from previous iterations of the NCHA survey [70]. Based

on results of other national surveys, previous years of the NCHA or NCHA II survey have been evaluated to determine generalizability of the resulting yearly datasets.

The purpose of this study is to examine current tobacco, polytobacco use, and perceived peer use over-time. The NCHA II survey is an ideal questionnaire for measures related to college populations. The survey provides a comprehensive examination of tobacco and substance use behaviors, with each having eight possible responses to assess frequency of current (past 30-days) and lifetime use (have used, but not in the last 30 days plus current use). From a national perspective, the NCHA II survey is one of a few national surveys examining these behaviors among US college students. Within the data set, institutions and respondents are completely de-identified. Nonetheless, the large number of institutions participating, the resulting large number of respondents provide one of the best available surveys for examining tobacco and substance use behaviors in college populations.

Measures and Recoding

Tobacco, Alcohol, and Marijuana Use: Single Behaviors

This study assessed current and ever (last 30 days) substance use of five tobacco behaviors including: cigarettes, tobacco from a waterpipe (hookah), cigars (little cigars, clove cigarettes, big cigars), smokeless tobacco, and e-cigarettes, in addition to alcohol (beer, wine, and liquor), binge drinking, and marijuana (pot, weed, hashish, hash oil). Tobacco, alcohol, and marijuana use behaviors were assessed as: "Within the last 30 days, on how many days did you use (*behavior)*:" Responses include: "Never used", "Have used, but not in the last 30 days", "1-2 days", "3-5 days", "6-9 days", "10-19 days", "20-29 days", or "Used daily". Binge drinking is

assessed as, “Over the last two weeks, how many times have you had five or more drinks of alcohol at a sitting?”. Responses include: “N/A, Don’t drink”, “None”, “1 time” through “9 times”, or “10 or more times”. All tobacco/substance use behaviors, except for e-cigarettes which was added in Fall 2015, were assessed in all survey years.

Current tobacco, alcohol, and marijuana use behaviors were recoded based on frequency of use into two- and three-level variables to assess individual behaviors by frequency of use in addition to polysubstance use behaviors. The two-level categories included: <u>Non-user</u> (“Never used”, “Have used, but not in the last 30 days”) and <u>Current user</u> (1 or more days in the last 30). The three-level variable categories included: <u>Non-user</u> (“Never used”, “Have used, but not in the last 30 days”), <u>Occasional user</u> (“1-9 days”), and <u>Frequent user</u> (10+ days). Binge drinking was also recoded into two and three-level variables as: <u>No binge drinking</u> or Current <u>binge drinking</u> (two-level); and <u>No binge drinking</u>, <u>Occasional binge drinking</u> (1 or 2 times), or <u>Frequent binge drinking</u> (3 or more times).

Responses to the current substance use item were used to define lifetime use. Individuals who were recoded as current users, in addition to those self-reporting “Have used, but not in the last 30 days”, where coded as <u>Lifetime users</u>. Individuals reporting “Never used” were coded as lifetime <u>Non-users</u>.

Polytobacco Behaviors

Polytobacco use behaviors were defined as using two or more tobacco products in the last 30 days and were assessed in two ways utilizing the two-level current use variables (use/no use). First, a variable was created that provided the overall number (sum) of behaviors each respondent reported, ranging from 0-5 behaviors. Based on the sum, the average number of

tobacco behaviors were calculated. Second, combinations of a single behavior and use of additional products used were coded for separately for each behavior similar to previous work [40]. The resulting variables were based on a polytobacco use with a tobacco product: including Polytobacco use with (cigarettes, hookah, cigars, smokeless tobacco, and e-cigarettes). By coding polytobacco with a tobacco product, the new variables condense a potentially large number of combinations.

Perception of Peer Use of Tobacco, Alcohol, and Marijuana

The NCHA II survey assesses social norms of tobacco and substance use through perception of peer use. Perception of peer use of cigarettes, hookah, cigars, smokeless tobacco, e-cigarettes, alcohol, and marijuana is assessed as: "Within the last 30 days, how often do you think the typical student at your school used (*behavior)*: (State your best estimate; Please mark the appropriate column for each row)". Responses include: "Never used", "Have used, but not in the last 30 days", "1-2 days", "3-5 days", "6-9 days", "10-19 days", "20-29 days", or "Used daily". Variables related to perception of peer use of tobacco, alcohol, and marijuana were recoded similarly to the two-level self-reported use variables. The two-level categories included: No perceived use ("Never used", "Have used, but not in the last 30 days") and Perceived current use (1 or more days in the last 30).

Demographics, Individual, and School Characteristics

Self-reported demographic, individual, and school characteristics were included as covariates in this study. Demographic and individual characteristics were self-reported whereas school characteristics were reported by each institution.

Demographic variables assessed in this study include: sex/gender, age, and race/ethnicity. For sex/gender, the dataset is distributed with a recoded variable that takes into account biological sex and a self-identified gender (three-levels: Male, Female, and Non-binary). Age is self-reported by respondents as a write-in response based on the following question: “How old are you?”. Race/ethnicity is assessed as: “How do you usually describe yourself? (Mark all that apply)”. Responses include: “White”, “Black”, “Hispanic or Latino/a”, “Asian or Pacific Islander”, “American Indian, Alaskan Native, or Native Hawaiian”, “Biracial or Multiracial”, or “Other”. To create a race variable for analysis, respondents who marked more than one answer, were recoded as “Biracial or Multiracial”. Upon examining the distribution of the recoded race variable, due to small numbers (less than 3% of all respondents for each category), three groups were collapsed into an “Other” category including: “American Indian, Alaskan Native, or Native Hawaiian”, “Biracial or Multiracial”, and “Other”.

Individual characteristics relating to non-demographic student information were also assessed in the survey including: year in school (1st-5th), participating in a Greek-letter organization such as a fraternity or sorority (yes/no), approximate grade point average (A, B, C, D/F), and campus residence (On-campus/Off-campus). Lastly, school characteristics related to the institution were assessed as measures of the institutional environment and include: region of campus (Northeast, Midwest, South, or West), population size of locality (≥50,000 or <50,000), public or private institution, and size of campus (large >10,000 or small/medium <10,000).

Inclusion Criteria and Study population

This study has several important inclusion/exclusion criteria. To be included in the study, participants must have been male or female undergraduates between the ages of 18-24 attending a US-based institution. Individuals identifying as a gender other than male or female, graduate

students, attending a 2-year institution, an institution outside of the US, or over the age of 24 were excluded from the analytic sample. For the purposes of this study, “college” students refer to students attending 4-year institutions. Prior to applying the exclusion criteria, the total sample was 900,305 consisting of 523 institutions. After applying the exclusion criteria, the analytic study sample was 619,546 and consisted of 415,698 females and 203,848 males at 483 institutions across eight academic years.

The data that was originally obtained for this study was by academic semesters of Fall and Spring. The Fall and Spring academic semesters were aggregated into academic years as rates of substance use were lower in Fall semesters than Spring semesters and the timing of surveys and rates of substance use throughout the academic year can be significantly different [71,72]. Differences in Fall and Spring semesters were seen when descriptive statistics on substance use by academic semesters were examined as Fall semesters tended to have lower rates of substance use than Spring semesters. Rather than completely excluding Fall 2015 from the study, it was included as e-cigarette use was added to the survey for the first time. Thus, for descriptive purposes, Fall 2015 is included, but was excluded from any prevalence rates reported in the Results section or subsequent analyses involving regression.

Statistical Analysis

Descriptive Results and Simple Linear Regression

Due to the exploratory nature of this study, a series of descriptive analyses were conducted for the full sample and separately for males and females by academic years. In the first step, descriptive statistics on demographic variables, individual characteristics, and institutional characteristics were examined. Second, prevalence rates were estimated for

Occasional, Frequent, Current (Occasional and Frequent), and Lifetime use of cigarettes, hookah, cigars, smokeless tobacco, e-cigarettes, alcohol, binge drinking, and marijuana. Third, prevalence rates of perception of current peer tobacco, alcohol, and marijuana use were examined for the full sample. Fourth, the total number (sum) and average number of tobacco behaviors were calculated. Fifth, prevalence rates of polytobacco use with tobacco products were assessed by tobacco behavior. Where applicable, the change in prevalence rates between 2008 and 2014 were calculated. Chi-square tests were used to test for significant differences between male and female subgroups for single- and polytobacco use behaviors.

For descriptive steps two through five, simple linear regression was applied to each behavior (prevalence rate, average, or sum) to examine the trend slope across the seven academic years (Fall 2008 to Spring 2015, excluding Fall 2015). The general equation for linear regression is $y_i = \left(\beta_0 + \beta_1 x_{i1} + ..\ \ \beta_j x_{ij} + e_i\right)$.

Where:

y_i = dependent variables, the observed response for each participant i (i.e. use or no use)

β_0 = constant. Expected mean value of Y when all X=0

$\beta_j X_{ij}$ = Slope, independent variables (study year)

e_i = error

The simple linear regression provides a slope estimate, the standard error of the estimate, a t-test, and the p-value of the t-test. The slope estimate provides a general direction and magnitude (positive = increasing, negative=decreasing) of the trend, while the t-test is a hypothesis test for the slope, testing that the slope is different from the null. The general equations for a t-test is: $t =$

$\beta_j \,/\, SE$, where β_j is the slope of the regression line divide by the standard error of the slope. The null hypothesis (H_0) for the t-test is that at least one slope parameter (β_j) is equal to $H_0 = \beta_j = 0$ indicating that the trend remained stable (did not increase or decrease). Whereas the alternative hypothesis is $H_A \neq 0$, indicating that the trend did not remain stable. For the t-test, a value is calculated based on the square root of an F-statistic. For this study, the t-test can be used and considered equivalent to a F-test because only one slope parameter is being tested as 0. A p-value of the t-statistic < 0.05 indicates a rejection the null hypothesis whereas a p-value ≥ 0.05 indicates a fail to reject the null hypothesis. Thus, for example, a t-test with a positive value and p-value < 0.05, in addition to a positive slope estimate indicates that the trend is increasing over time and a t-test with a negative value, a p-value < 0.05, in addition to a negative slope estimate indicates the trend is decreasing over time. Additionally, a p-value ≥ 0.05 should have an accompanying slope estimate and t-test value close to 0, indicating that the trend has remained stable.

Logistic Regression

A series of multivariate logistic regression tests were conducted controlling for study year, school identification, and age. The purpose of controlling for study year and school is to account for any cohort effects as individuals who were users are more likely to be similar to peers their own age or grade at the same schools. The first set of multivariate logistic tests examined the relationship between perceiving peer use of each substance and self-reported use of that substance. The second set of models examine the relationship between each polytobacco use behavior and demographics, student characteristics, and institutional variables. Additionally, the relationship of current alcohol use, binge drinking, marijuana use, and the number of perceived peer behaviors with each polytobacco use behavior were also examined by gender.

All logistic regression models were adjusted for multiple testing comparisons. The issue of multiple comparisons occurs when an analysis involves multiple tests of the same type, having the potential to produce a false discovery based on a standard p-value of 0.05 [73]. To correct for this, multiple methods, including the Bonferroni multiple comparisons adjustment used in this study, allow for calculation of a new level of significance. In this study, the logistic regression analyses were stratified by male and female. Within each gender analysis, there were 13 variables being tested against four groups of polyusers. Thus, there were 52 different tests. The significance level of 0.05 was divided by 52, producing the new significance level of 0.001. Therefore, only adjusted odds ratios with a p-value <0.001 will be considered significant.

RESULTS

Study Demographic, Student, and Institutional Characteristics

Study samples by academic year ranged from 77,952 – 96,209 in the full academic years (Fall 2008-Spring 2015) and 13,409 in the added Fall 2015 semester (Table 2.1). Overall 67% of the sample was female, 69% were white, the average age of respondents was 20.0 (SD=1.52) and 8.5% self-reported being non-heterosexual. Over half of respondents lived on campus, 29% were in their first year, 19% participated in a Greek-letter organization such as a Fraternity or Sorority, and nearly 88% had an average GPA of a B or higher. Over half of the participating institutions were in the South or Northeast (56%), 62% were public, 59% had student populations greater than 20,000, and 65% were located in a city or town with a population less than 50,000.

Trends of Tobacco, Alcohol, and Marijuana Use: Single Behaviors

Current, Occasional, Frequent, and Lifetime Use: Entire Sample

Among the entire sample, current (past 30-day) and lifetime use of nearly all tobacco behaviors decreased over the study duration (Table 2.2). For the purposes of describing current prevalence rates, Fall 2015 is not included as it was not an aggregated academic year and rates in Fall semesters tended to be much lower than Spring semesters or academic years.

Tobacco Use: Cigarettes

Rates of current and lifetime use of cigarettes in the entire sample decreased across the study period. The prevalence of current cigarette smoking significantly decreased by 5.3% from the highest prevalence of 16.4% to 10.1% between Fall 2008 and Spring 2015, making cigarettes the most currently used tobacco product. Current use of cigarettes was nearly equal between occasional and frequent users and of the 10.1% of respondents reporting current cigarette use in Spring 2015, over 65% of them were occasional users (1-10 days). Lifetime use of cigarettes also significantly decreased over the study period, dropping from a peak of 33.0% to 23.4%.

Tobacco Use: Hookah

Rates of current and lifetime use of hookah (tobacco from a waterpipe) in the entire sample significantly decreased over the study period, however the decrease was the smallest overall decrease of any tobacco product. Current use of hookah significantly decreasing from 10.0% to 8.5% between Fall 2008 and Spring 2015 and peaking at 10.2% in Fall 2012/Spring 2013. Nearly all current hookah users were occasional users using between 1-10 days out of the last 30. Lifetime use of hookah significantly decreased by 2.2% from 33.0% to 30.8% over the

study period and peaking at 34.2% in Fall 2012/Spring2013, making hookah the most tried tobacco product.

Tobacco Use: Cigars

Rates of current and lifetime use of cigars (including big cigars, little cigars, cigarillos, and clove cigarettes) in the entire sample significantly decreased over the study period. Current cigar use significantly decreased by 3.5%, from a peak of 8.5% to 5.0% between Fall 2008 and Spring 2015. Nearly all cigar users were occasional users, using between 1-10 days out of the last 30. Lifetime use of cigars significantly decreased by 9.0% from a peak of 29.4% to 20.4% over the study period.

Tobacco Use: Smokeless Tobacco

Rates of current and lifetime use of smokeless tobacco in the entire sample significantly increased across the study period, however it was the least used tobacco product. Current use significantly increased from 3.8% to 3.9% between Fall 2008 and Spring 2015, peaking at 5.1% in Fall 2013/Spring 2014. Additionally, there was a nearly an equal split in current use between occasional and frequent use. Lifetime use significantly increased by 1.2% from 10.7% to 11.9%, peaking at 13.1% in Fall 2013/Spring 2014.

Tobacco Use: E-cigarettes

Questions related to e-cigarette cigarette use were added to the NCHA II in Fall 2015. Thus, only a single semester of e-cigarette prevalence is available and trends are not able to be established. Nonetheless, the prevalence of current e-cigarette in Fall 2015 was 5.2% while lifetime use was 16.6% in the entire sample.

Alcohol Use and Binge Drinking

Rates of current and lifetime alcohol use and current binge drinking in the entire sample significantly decreased. Past 30-day alcohol use significantly decreased by 3.9% from a peak of 67.1% to 63.2% between Fall 2008 and Spring 2015. Past 2-week binge drinking significantly decreased by 3.6% from a peak of 38.5% to 34.9% between Fall 2008 and Spring 2015. Over each academic year, nearly three-fourths of current alcohol use was occasional use (1-10 days). Lifetime use of alcohol decreased by 2.9%. from a peak of 79.9% to 77.0%.

Marijuana Use

Marijuana use in the entire sample significantly increased for both current and lifetime use across the study period. Past 30-day use significantly increased by 3.1% from 16.5% to a peak of 19.6% between Fall 2008 and Spring 2015. About two-thirds of current users were occasional users using between 1-10 days. Lifetime use of marijuana significantly increased by 4.5% from 35.0% to a peak of 39.5%.

Current, Occasional, Frequent, and Lifetime Use: Female and Males Samples

Overall, males had higher rates of current and lifetime use of all tobacco behaviors, however they also had larger decreases in use than females (Tables 1.3 and 1.4). Additionally, males had higher rates of current binge drinking, current and ever marijuana use and similar rates of current and ever alcohol use than females.

Tobacco Use: Cigarettes

Rates of current and ever cigarette use among males and females significantly decreased across the study period. Among males, rates of current cigarette use decreased from a peak of

19.8% to 13.8%, whereas among females, use significantly decreased from a peak of 14.7% to 8.5% (males: 6.0% decrease; females: 6.2% decrease). For use frequency, 58% of male cigarette users were occasional users compared to 63% of female cigarette users. Among males, lifetime use significantly decreased from a peak of 36.4% decreasing to 28.4%. For females, a peak of 31.3% reported lifetime use decreasing to 21.1% (males: 8.0% decrease; females: 10.2% decrease). The overall significantly decreasing trends in male and female current and ever cigarette use was significant based on slope estimates and t-values. However, based on the percent change from 2008 to 2015 and the slope estimates, females had larger declines in use. Nonetheless, the declines in cigarette use for both females and males were the largest declines for any tobacco behavior.

Tobacco Use: Hookah

Rates of current and ever hookah use (tobacco from a waterpipe) among males and females significantly decreased across the study period. Among males, rates of hookah use peaked at 13.2% significantly decreasing to 10.5%, whereas among females, rates peaked at 8.4% significantly decreasing to only 7.6% (males: 2.7% decrease; females: 0.8% decrease). For males and females, nearly all were occasional users using between 1-10 days out of the last 30 days. Lifetime use of hookah in males significantly decreased from 37.8% to 34.0% and (non-significantly) from 30.5% to 29.3% in females with both groups having peaks in use during Fall 2012/ Spring 2013 of 34.2% and 32.1% respectively (males: 3.8% decrease; females: 1.2% decrease).

Tobacco Use: Cigars

Rates of current and ever cigar use (including big cigars, little cigars, cigarillos, and clove cigarettes) among males and females significantly decreased across the study period. Among males, rates of cigar use peaked at 15.3% significantly decreasing to 10.1%, whereas among females, rates peaked at 5.1% significantly decreasing to 2.6% (males: 5.2% decrease; females: 2.5% decrease). For males and females, nearly all were occasional users using between 1-10 days out of the last 30 days. Lifetime use of cigars in males significantly decreased from a peak of 42.5% to 33.2% and from a peak of 22.8% to 14.5% in females (males: 3.8% decrease; females: 1.2% decrease).

Tobacco Use: Smokeless Tobacco

Rates of current and ever smokeless tobacco among males decreased and while rates among females significantly increased across the study period. Among males, rates of smokeless tobacco use peaked at 10.5% in Fall 2014/Spring 2015, but overall decreased from 8.9% to 8.6%. Among females, rates peaked at 2.5% in Fall 2014/Spring 2015, but overall significantly increased from 1.2% to 1.7% (males: 0.3% decrease; females: 0.5% increase). Male current users were relatively split between occasional (using between 1-10 days) and frequent use (10+ days) out of the last 30 days while females were nearly all occasional users. Lifetime use of smokeless tobacco in males peaked at 23.4% in Fall 2013/Spring 2014, but overall decreased from 20.9% to 20.7%. Lifetime use in females significantly increased from 5.6% to 7.8%, peaking at 8.1% in Fall 2013/Spring 2014 (males: 0.2% decrease; females: 2.2% increase). The overall increasing trends of current and ever smokeless tobacco use for was significant based on slope estimates and t-values, however the decreasing trend for males was not significant, suggesting that trends of current and ever smokeless tobacco use for males has remained stable.

Alcohol Use and Binge Drinking

Rates of current alcohol and binge drinking and ever alcohol use significantly decreased for males and females across the study period. Among males, alcohol use peaked at 68.5% and significantly decreased to 62.6%. Among females, rates peaked at 66.4% and significantly decreased to 63.5% (males: 5.8% decrease; females: 2.9% decrease). Male current users were relatively split between occasional (using between 1-10 days) and frequent use (10+ days) with about two-thirds being occasional users out of the last 30 days. Among female current alcohol users however, approximately 80% were occasional users. Lifetime use of alcohol in males peaked at 79.6% and significantly decreased to 75.2% and in females peaked at 80.0% and significantly decreased to 77.9% (males: 4.4% decrease; females: 2.1% decrease). Rates of current binge drinking among males significantly decreased from 38.5% to 34.9% with most users being frequent users (using 3 or more times in the last 2 weeks), while rates in females significantly decreased from 48.7% to 42.4% with more users being occasional (1-2 times in the last 2 weeks) users (males: 6.3% decrease; females: 3.0% decrease).

Marijuana Use

Rates of current and ever marijuana use ((pot, weed, hashish, hash oil) among males and females significantly increased across the study period. Among males, rates of current marijuana use significantly increased from 20.8% to 23.6% and peaking at 23.8% in Fall 2014/Spring 2015. Among females, current use significantly increased from 14.3% peaking to 17.7% (males: 2.8% decrease; females: 3.4% decrease). There was nearly an even split between occasional use (1-10 days) and frequent use (10+ days) in the past 30 days in males, whereas for females most were occasional users. Lifetime use of marijuana in males significantly increased from 39.2% to a

peak of 42.8% and from 32.9% peaking at 37.9% in females (males: 3.6% decrease; females: 5.0% decrease).

Polytobacco Use

Among the entire sample, 8.2% of respondents were polytobacco users across the study period and on average, respondents on average took part in 0.34 tobacco behaviors. Polytobacco use by gender was significantly different as 14.2% of males and 5.4% of females were polytobacco users across the study period (Table 2.5). On average, males used 0.51 tobacco products and females 0.25. However, in the full sample, in males and in females, the trend decreased over time. The decreasing trend indicates that across the study period, rates of tobacco and poly tobacco use were decreasing or that rates of no tobacco use were increasing. In the full sample, 77.4% of respondents did not use a tobacco product, 14.6% used one, and 8.2% used two or more. Across the full sample, the prevalence of no tobacco use increased from 74.4% and peaking at 81.3%. A reverse trend existed for single-product tobacco use (significant decrease from 16.2% to 12.4%) and polytobacco use (significant decrease from 9.4% to 6.3%). Examining the prevalence of polytobacco use and trends by gender however displayed similar overall decreasing trends, but at different magnitudes between males and females. Overall, 81.5% of females were non-tobacco users, 13.3% single-product users, and only 5.4% polytobacco users. Across the study period for females, single tobacco product use decreased from 15.0% to 11.1% and polytobacco use decreased from 5.4% to 4.0%. In males, 69.0% were non-tobacco users, 17.3% single-product users, and 14.2% polytobacco users. In males, single-product use decreased from 18.4% to 15.2% and polytobacco use decreases from 15.8% to 11.1%. Trends for single-product and polytobacco use in males and females were significant.

Polytobacco Use with Tobacco Product Types

Trends of polytobacco use were examined were examined with tobacco products were assess in two ways: first, overall prevalence of polytobacco use with a tobacco product (cigarettes, hookah, cigars, smokeless tobacco, and e-cigarettes) for each sample (entire, females, and males) was assessed (Table 2.6); and second, the prevalence of use of each tobacco product in polytobacco users for each sample was determined (Table 2.7).

Of all respondents, 6.5% (4.5% females, 10.6% males) of respondents were polytobacco users who smoked cigarettes, 5.2% (3.8% females, 8.1% males) polytobacco users who use hookah, 4.7% (2.6% females, 9.0% males) polytobacco users who smoked cigars, 2.7% (1.0% females, 6.1% males) polytobacco users who used smokeless tobacco, and 5.2% (3.6% females, 8.9% males) polytobacco users who use e-cigarettes across the study period (Table 2.6). Polytobacco use with use of each tobacco product significantly decreased for the entire sample, for males, and for females, except for polytobacco user and smokeless tobacco user in males, which remained stable.

Among polytobacco users in the entire sample cigarette smoking was the most common with 81.3% on average smoking cigarettes. In all polytobacco users, cigarette smoking peaked at 84.6% and significantly decreased to 78.0%. In female polytobacco users, cigarettes were used by 86.3% with use significantly decreasing from 90.2% to 82.8% over the study period. In male polytobacco users, cigarette smoking overall was used by 77.4% with use significantly decreasing from 80.2% to 74.3% over the study period.

Hookah was the second most common tobacco behavior for polytobacco users in the entire sample and in females with 65.1% of the entire sample, 72.8% of females, and 59.1% of

males using hookah. Use of hookah in polytobacco users significantly increased across the study period for the entire sample. In all polytobacco users, hookah use significantly increased from 63.5% to 67.6% over the study period. In female polytobacco users, hookah use significantly increased from 69.6% to 75.9% over the study period.

Cigars were the third most used tobacco product among polytobacco users in the entire sample overall, second most common for males, and fourth most common for females. Among polytobacco users in the entire sample, overall 58.5% were cigar users and use significantly decreasing from 63.4% to 53.2% across the study period. In female polytobacco users, 49.2% used cigars with use significantly decreasing from 57.2% to 41.7% across the study period. In male polytobacco users, 65.7% used cigars with use significantly decreasing from 68.3% to 62.2% across the study period.

Smokeless tobacco was the least used tobacco product among the entire sample, females, and males, but increasing in use. Only 33.1% of polytobacco users in the entire sample with, but use significantly increased from 26.1% to 41.0% across the study period. In female polytobacco users, 18.6% used smokeless tobacco, significantly increasing from 10.8% to 27.3%. In male polytobacco users, 44.3% used smokeless tobacco with use significantly increasing from 38.3% to 51.8% across the study period.

While e-cigarette use was only assessed in one period and trends are not able to be established, among polytobacco users, e-cigarettes were the fourth most common product in the entire sample (52.8%) and in males (52.2%) and the third most common product in females (53.6%).

Perceived Peer Use of Tobacco, Alcohol, and Marijuana

On average, respondents perceived that their peers used 2.80 tobacco products (Table 2.6) and the average number of perceived products was higher for females (2.85) than for males (2.69). Overall, prevalence of perceived peer use of tobacco, alcohol, and marijuana followed similar trends to use of single behaviors (Table 2.8). Rates of perceived peer use of tobacco ranged from 60% to over 80% depending on the product. Perceived peer use of cigarettes and cigars significantly decreased in the entire sample and in male and female samples across the study period. Perceived peer use of hookah significantly increased in the entire sample similar to females. However, perceived peer of hookah decreased for males, but the trend was not significantly different from a stable trend. Perceived peer use of smokeless tobacco significantly increased for males and females across the study period. Perceived peer use of alcohol significantly decreased for males and females across the study period whereas perceived peer use of marijuana significantly increased for both groups.

Associations between perceived peer use and self-reported tobacco use were examined (Table 2.9). Controlling for study year, institution identification number, and age, all models examining peer use were moderately and significantly associated with self-reported tobacco use (aOR range: 2.04-2.95). Associations for cigarettes (females: 2.16 [95% CI 2.09-2.23]; males: 2.12 [95% CI 2.05-2.20]), hookah (females: 3.33 [95% CI 3.20-3.44]; males: 2.84 [95% CI 2.73-2.94]), and cigars (females: 2.48 [95% CI 2.37-2.58]; males: 2.30 [95% CI 2.23-2.37]) between perceived peer use and self-reported use were stronger for females than male. This was reversed for smokeless tobacco (females: 2.11 [95% CI 2.00-2.24]; males: 3.32 [95% CI 3.20-3.45]), where males had the overall strong association. The associations among each sample for e-

cigarettes however were nearly equal (females: 2.43 [95% CI 1.70-3.48]; males: 2.41 [95% CI 1.79-3.25]).

Factors Associated with Polytobacco use

After controlling for study year, school identification number, and age, an increased number of perceived peer behaviors was significantly associated with being a polytobacco user and user of cigarettes (aOR range: 1.54-2.91), hookah (aOR range: 1.50-2.77), cigars (aOR range: 1.33-2.89), and smokeless tobacco (aOR range: 1.32-3.01) in females as well as males (Table 2.10 and Table 2.11). In general, for each increasing number of perceived peer behaviors (range: 1-5) the magnitude of the association also increased, particularly for males. While there were moderately significant associations among females, the magnitude of associations for males was greater as the number of perceived behaviors increased. The association between polytobacco use and e-cigarette use and any number of perceived peer tobacco use behaviors was not significant for either males or females.

The strongest associations for being a polytobacco and cigarette, hookah, cigar, or smokeless tobacco user was for the non-tobacco substance use including alcohol (aOR range: 6.97-12.20), binge drinking (aOR range: 4.69-7.85), and marijuana use (aOR range: 4.53-9.05). Polytobacco and cigarette use was strongly associated with alcohol, binge drinking, and marijuana use in males and females. Additionally, the nontobacco behaviors were also strongly associated with all of the polytobacco with each tobacco product. The overall magnitude of these associations was stronger for males than females across all associations.

Among demographic characteristics, non-white race/ethnicity was generally a protective factor for all polytobacco use in males and females. Non-heterosexual respondents were more

likely to be polytobacco user and users of cigarettes or hookah compared to heterosexual respondents in males and females. However, non-heterosexual male respondents were less likely to be a polytobacco user and cigar or smokeless tobacco users. In females, non-heterosexual respondents were more likely to use cigars and smokeless tobacco than heterosexual women. For both females and males, living off campus was moderately associated with polytobacco use (OR range here) and being a user of cigarettes, hookah, cigars, or smokeless tobacco (aOR range: 1.09-1.23). Being beyond the first year in school was generally not associated with being a polytobacco and cigarette, hookah, cigar, or smokeless tobacco user for males with only a few associations. Similarly, there were few associations regarding year in school for females, but the significant associations that did exist were protective, indicating that females are more likely to use in their first year. Participating in a Greek-letter organization and approximate grade point average (GPA) were both highly associated with polytobacco and cigarette, hookah, cigar, or smokeless tobacco use (aOR range: 1.09-1.23). Participating in a fraternity or sorority was moderately associated with polytobacco use and all tobacco behaviors in males (aOR range: 2.26-2.61), but not significant females. As GPA fell in females and males, individuals became more likely to be polytobacco and cigarette, hookah, cigar, smokeless tobacco, or e-cigarette users than users with a 4.0 average (D/F aOR range: 2.51-3.35). Males living in the South or Midwest were more likely to be polytobacco and cigarette, hookah, cigar, or smokeless tobacco users than those living in the Northwest, whereas females from the Northeast were more likely to be polytobacco and cigarette or hookah users. Lastly, attending a large or public institution was associated with polytobacco and cigarette, hookah, cigar, or smokeless tobacco use in males but not for females.

DISCUSSION

This study provides one of the most comprehensive examination of trends and relationships of single-product tobacco use, polytobacco use, and perception of peer tobacco use in a college students by utilizing a national data set of 15 consecutive academic semesters between Fall 2008 and Fall 2015. While previous work has examined polytobacco use in college students using one-time cross sectional surveys [29,74] and combinations of polysubstance and polytobacco use [23,53,74], no known study to date has examined trends of polytobacco use or the relationship with perception of peer use. Furthermore, studies examining tobacco in college populations often do not assess gender separately, which proved to be highly important to this study as rates of polytobacco use were significantly different between females (5%) and males (14%) and specific risk factors of use were observed. While previous studies have highlighted the differences in polytobacco use between genders, particularly in adults, one of the goals of this study was to assess how the relationships with demographic and other characteristics with polytobacco use were different by gender. If gender was assessed as a covariate and examined the relationship between each polytobacco with single tobacco use types, results based on genders would have been suppressed.

Polytobacco Use

Rates of current polytobacco use in this study ranged from 6.3% to 9.4% in the entire sample, from 4.0% to 6.2% in females, and from 11.1% to 15.8% in males. Overall, trends of polytobacco use are decreasing among college populations, but individuals who are polytobacco users, are at an increased risk for negative health outcomes and nicotine dependence [75]. Rates of polytobacco use and polytobacco use with specific tobacco behaviors were both similar and different from previous work. These differences are reflected in the use of specific subgroups

and differing definitions and behaviors included in polytobacco use. Yu et al. recently published research examining polytobacco use based on results from an internet study of ~1400 college students [74]. While the overall study sample is small, the study observed that 24.3% of respondents reported using two or more tobacco products in the last 30 days [74]. The poly-use results in the Yu et al. study appear to be much higher than the range of prevalence rates observed in this study. In a similar study, Butler et al. reported that among college students who reported being ever tobacco users, approximately 15% of lifetime users reported current polytobacco use, which is similar to the results this study found for males early in the study period [29]. Taking a different approach to polytobacco use, a study using latent class analysis, observed that 20% of users were past 30 day polytobacco use [23]. While two of these three studies found higher rates of polytobacco use, the overall sample size and the ability to examine trends in this study provide better estimates of polytobacco use in college populations. In addition to studies exclusively examining polytobacco use in college students, other studies have examined polytobacco use in adult populations at different age ranges. One such study found that rates of polytobacco use by cigarette, cigar, chewing tobacco, and snuff vary widely and only observed that 8% of cigarette smokers were polytobacco users compared to 42-52% for other tobacco use [40]. These results are in contrast to this study which observed that cigarette smoking among polytobacco users (81.3%) was higher than use of hookah (65.1%), cigars (58.5%), smokeless tobacco (33.1%), or e-cigarettes (52.8%). Additionally, while that study did examine polytobacco use over four different time periods (1998, 2000, 2005, and 2010) they generally found that polytobacco use was increasing or remained stable in adults, whereas this study observed that among college students, rates of polytobacco use appear to be declining overall. The differences in polytobacco use rates in the Sung et al. study and this study could be

explained by increasing use of alterative products in college students such as hookah and e-cigarettes, which were not assessed in that study, or differences college populations characteristically and behaviorally have from a general adult population.

Only a few studies have examined factors related to polytobacco use among in college student or adult populations [23,26,29,40,74]. This study observed that factors differed by polytobacco use behaviors and by gender, which has rarely been studied. By stratifying the sample to males and females, this study was able to report not only polytobacco use rates, but which products are being most used by polytobacco users and the characteristics and factors related to polytobacco use separately for males and females. Males across the study period and among specific behaviors had higher rates of polytobacco use, but both groups had a similar decreasing trend magnitude (i.e. decreasing at about the same rate). Cigarette smoking was particularly common among male polytobacco users with on average, 86% of polytobacco users smoking cigarettes compared to 77% of females. While cigarettes were the most popular behavior for polytobacco using males and females, hookah use was the second most common in females and cigar use the second most common in males. Hookah use fell to the third most common in males while e-cigarettes were the third most common in females. Based on these results, there are clear differences in which behaviors males and females are using, but cigarettes remain the product of choice for both groups in regard to polytobacco use.

Polytobacco use with tobacco behaviors differed by specific factors within and between males and females. In general, the strongest associations for females were being non-heterosexual, having a GPA below a 4.0, using alcohol, marijuana, or binge drinking and perceiving peer use of tobacco. For specific tobacco products used as polytobacco using females, there were generally no within differences, meaning that if they were polytobacco users, they

generally had an increased likelihood to use any of the products. Comparatively for males, being white, participating in a Greek organization, having a GPA below a 4.0, using alcohol, marijuana, or binge drinking and perceiving peer use of tobacco. The magnitude of these relationships also different by product at polytobacco use with cigarettes and cigar had the strongest associations. Nearly all of these characteristics are known predictors of tobacco use based on previous research [29,30,74,76]. Unsurprisingly, alcohol use, binge drinking, and marijuana use were the strongest predictors in males and females, highlighting the need to address other substance use along with tobacco use in interventions or cessation programs [77,78].

Single-Product Tobacco Use

Trends of single-product tobacco current and lifetime use in this study are similar across all tobacco behaviors (cigarette, hookah, cigar, smokeless tobacco, and e-cigarettes) and non-tobacco behaviors (alcohol, binge drinking, and marijuana) assessed to the *Monitoring the Future* study, particularly for differences between genders. In 2015, *MTF* found that 16% of males and 9% of females were past 30-day cigarette smokers, which were lower than rates in this study (9% for females and 14% for males) [11]. The rates of past 30 day uses of this study were similar to other work [21,22] and the majority of cigarette users in males and females being occasional users supports that college students are transitioning to nondaily use [30]. Males in this study, were more likely to be frequent users. The decreasing trend of use observed in this study is also reflected by *MTF*.

Hookah use in *MTF* is examined as annual prevalence, which is not assessed in this study. Nonetheless, rates of hookah use have been assessed previously using NCHA II data from 2010 and were identical to this studies' results for that year (10% in entire sample) [46]. In Fall 2014/Spring 2015, 8% of females and 11% of males were current hookah users which is similar

to other work [15]. Unsurprisingly, the vast majority of hookah users were occasional users as hookah is often used in social settings [35]. The decreasing trend of current hookah use in this study reflects the decreasing annual use reported in *MTF*. Cigar use in MTF is assessed for big cigars, little cigars, and flavored little cigars separately and rates range from 7-9% in males and from 4-15% in females. Rates in this study were assessed as a single cigar use variable that included those examined by *MTF*. Current cigar use in females for this study was 3% and 10% for males. An additional study by Sterling et al. found that 12% of respondents (10% of females and 18% of males) were small cigar users [55]. Smokeless tobacco use for *MTF* is assessed among all young adults with 2% of females and 11% of males in 2015 which is similar to rates in this study (2% for females, 9% for males Fall 2014/Spring 2015) [11] and other research [79]. E-cigarette use in this study was assessed only for Fall 2015. While Fall semesters had lower rates of all substance and tobacco use than Spring semesters, Fall 2015 was assessed in the study specifically for e-cigarettes. Rates of electronic vaporizer use in *MTF* was 5.8% in females and 14.4% in males, which were higher than this study (4% for females, 9% for males).

For non-tobacco behaviors, *MTF* reported that 63% of females and 64% of males were alcohol users, 29% of females and 37% of males were binge drinkers, and 25% of males and 19% of females were marijuana users in 2015. Rates of alcohol use in this study were higher for females (77.9%), but similar for males (63%) for Fall 2014/Spring 2015. Rates of binge drinking in this study were slightly higher than *MTF* with 31% of females and 42% of males for Fall 2014/Spring 2015. Lastly, marijuana use in this study was consistent with *MTF* with 18% of females and 24% of males being users for Fall 2014/Spring 2015.

Perception of Peer Use and Tobacco Use

Perception of peer use was moderately significant with single tobacco behaviors, but strongly associated with polytobacco use behaviors. The associations between perceived peer use and polytobacco use increased in magnitude as individuals perceived that their peers used more behaviors. Perceptions of peer use also appear to follow trends similar to single-product tobacco and polytobacco use. As both forms of tobacco use declined over the study period, perceptions of peer use also declined. Misperceptions of college student peer tobacco, alcohol, and drug use and social acceptability has long been established [80-84]. The 2012 Surgeons General's report on "Preventing Tobacco Use Among Youth and Young Adults", specifically highlights acceptability and the influence of peer groups as major factors in youth young adult tobacco use [7]. Social acceptability and perception of peer use in particular, are related to the social normative within the college environment [13,80,85]. While each social acceptability and norms have been researched for each tobacco product [28,86], little to no work has examined collective perceptions of tobacco in college populations. This results from this study suggest that individuals perceive that their peer on average use over two tobacco products, but use less than one. The results and the associations observed in this study suggest that addressing misperceptions related to peer tobacco and polytobacco use could impact the overall social norm and in turn impact rates of tobacco use.

Study Limitations

This study has several important limitations. First, the surveys in each period are cross-sectional and therefore, causality and temporality cannot be fully established. Nonetheless, this study's main goal was to examine trends of tobacco and polytobacco use in college students which was accomplished. Additionally, the large sample sizes and number of schools

participating in the survey over the study period provide results that can be generalized to US college students. While the study is based on repeated cross-sectional surveys and respondents are not followed over time, the results provide some of the best available estimates on college tobacco and polytobacco use over the last decade. Second, Fall dataset had lower rates of tobacco and substance use than Spring data sets. Thus, the Fall and Spring data sets were combined to create an academic year. A plausible reason Fall had lower rates of tobacco and substance use is that the timing of survey administration could lead to underreporting in students that take the survey early in the Fall semester. Fall semesters traditionally also have lower rates of tobacco and substance use [87]. Third, e-cigarettes were added to the survey in the last semester data available and the resulting semester, does not have a corresponding Spring data set to create a full academic year. Furthermore, Fall data sets had lower prevalence rates of tobacco and substance use compared to Spring data sets. Therefore, Fall 2015 was included in the overall study period, but was not used in assessing trends using linear regression. Fourth, polytobacco use is highly difficult to measure and define from a data perspective as there are a large number of potential combinations of tobacco use by product. Studies have examined polytobacco use from the perspective of the individual utilizing methods such as methods like and related to latent class analysis (LCA), which provides the most likely combinations based on self-reported responses. While these methods are useful for defining the combinations, they have the potential to misclassify individuals to the wrong class and often are not sensitive enough to determine the "true" number of combinations. Thus, this study takes a different approach to examine the trends of use over time. Lastly, there were differences in overall sample sizes between males and females, however the large sample size of this study and the proportions by gender are similar to proportions reported by the National Center for Education Statistics[88].

Implications and Conclusions

Tobacco use trends among college populations have continued to decrease over the last decade [11] and results from this study support the decreasing trends. Nonetheless, nearly one in five college students in this study reported being current users of at least one tobacco product and nearly one in ten currently use multiple tobacco products (polytobacco use). Tobacco use, particularly polytobacco use, increases the likelihood of negative health outcomes, nicotine dependence, and use of other alcohol and marijuana [23,53,74,75]. While the decreases in single-product tobacco and polytobacco use are promising, the need for comprehensive education, interventions, and cessation services still is needed, particularly for the risks associated with polyuse of tobacco. The overall decreasing trends of use could signal that current efforts to address tobacco use in young adults and college students are effective, however many of the trends changes appear to be stabilizing suggesting that declines will not continue as rapidly.

The rates of lifetime and current tobacco and declines overtime were different for males and females. Males continue to use more tobacco product types and in heavier frequencies and are more likely to be polytobacco users than females. There were also specific differences in risk factors for polytobacco use. The differences in use between females and males highlights the need for interventions to specifically address and focus on male populations, including subgroups like males within Greek-letter organizations. Among females, while those in the Greek-letter organizations were more likely to take part in specific combinations of polytobacco use, non-heterosexual females were likely to use all polytobacco use behaviors. This was an interesting finding as non-heterosexual males are often likely to be tobacco users [89], but in this study, were observed not to be. Future interventions need to target male and female populations differently and further analysis of this data could prove useful for developing targeted

information on the specific subgroups between genders that are at the highest risk. The availability of this data and the large sample sizes will allow for future exploration of use in subgroups that are often underrepresented in research regarding college tobacco and substance use. These results should encourage college campuses to take action to reach such groups if declines in use are to continue. This could be done through affordable university housing, addressing other substance use, changing the social norms on campus and in Greek-letter organizations, reaching out to students suffering from mental or other health issues, and assisting those obtaining low grades. College is a time period for advancement in knowledge and personal growth, but also is a significant opportunity for development of healthy behaviors.

In conclusion, while the declining trend of tobacco use found in this study is a promising result in for overall tobacco use rates, nearly one in four college students still used at least one tobacco product and nearly one in three tobacco users, were polytobacco users. Furthermore, the advancement of new products into the tobacco marketplace will continue to affect the overall use of tobacco in college populations due to the addictiveness of nicotine and strong relationships with other substance use. As the marketplace for tobacco use grows, college users will continue to diversify their tobacco use and future interventions. Future policy should focus on deterring college students from using tobacco-based products. This focus is expected to improve population-level outcomes in individuals well beyond their years in the university.

Table 2.1. Demographics of the National College Health Assessment II, 2008-2015

		Overall	2008 [a]	2009 [a]	2010 [a]	2011 [a]	2012 [a]	2013 [a]	2014 [a]	2015[b]
Study Sample (N)		619 546	77 952	83 765	96 023	84 812	96 209	82 076	85 300	13 409
Gender	Female	67.1	66.5	65.6	66.3	67.3	68.0	67.5	68.3	68.6
	Male	32.9	33.5	34.4	33.7	32.7	32.0	32.5	31.7	31.4
Race[1]	White	69.3	73.5	73.2	70.0	70.5	66.3	69.8	62.7	69.2
	Black	5.0	4.8	5.3	5.4	4.4	5.3	4.7	4.9	6.6
	Hispanic	9.0	8.2	8.0	8.9	9.2	9.5	8.1	11.2	6.4
	Asian	9.2	6.8	6.7	8.7	8.2	11.2	9.7	12.7	9.6
	Other	7.5	6.6	6.8	7.0	7.6	7.6	7.8	8.6	8.2
Age (mean and SD)		20.0 (1.52)	20.0 (1.48)	20.0 (1.55)	20.0 (1.51)	20.1 (1.51)	20.1 (1.52)	20.0 (1.50)	20.0 (1.53)	19.8 (1.53)
Non-Heterosexual		8.5	6.3	6.6	7.6	8.2	8.2	9.7	11.2	16.7
Lives on campus		56.1	59.5	55.3	57.5	54.8	53.9	58.3	54.6	53.1
Year in School	1st	29.4	30.1	31.2	30.0	28.0	28.8	28.8	29.1	30.6
	2nd	23.2	22.9	22.6	24.2	22.9	23.2	23.3	23.2	23.1
	3rd	23.3	23.5	22.4	23.2	23.7	23.5	23.3	23.4	22.5
	4th	19.3	19.0	18.7	18.5	20.2	19.4	20.2	19.2	18.3
	5th	4.8	4.5	5.2	4.1	5.3	5.1	4.5	5.0	5.5
Fraternity or Sorority		19.3	19.0	18.7	18.5	20.2	19.4	20.2	19.2	18.3
Approx. GPA	A	37.5	36.0	36.3	36.9	38.7	37.2	39.2	37.8	41.4
	B	50.2	51.3	50.9	50.3	49.7	50.2	49.5	50.0	48.3
	C	11.6	12.0	12.2	12.1	11.0	11.8	10.7	11.5	9.7
	D/F	0.7	0.7	0.7	0.8	0.7	0.8	0.6	0.7	0.6
Region	Northeast	26.9	29.5	23.5	32.4	20.6	29.3	28.1	24.4	26.4
	Midwest	19.0	25.7	16.2	17.6	17.1	20.9	15.3	22.3	8.6
	South	29.1	27.1	30.6	29.4	34.4	26.7	28.6	24.8	42.1
	West	25.0	17.8	29.8	20.6	28.0	23.1	28.0	28.5	22.9
Inst. Type	Public	62.1	59.5	64.3	62.1	62.4	62.8	58.1	64.3	67.0
	Private	37.9	40.5	35.7	37.9	37.6	37.2	41.9	35.7	33.1
Locale Size	Small <50k	64.9	68.8	61.2	65.2	64.0	70.7	52.0	71.8	63.0
	Medium 50-250k	26.2	20.3	31.6	22.9	26.7	21.8	36.6	23.1	35.7
	Large >250	8.9	10.9	7.2	11.9	9.3	7.6	11.4	5.1	1.3
Campus Size	Small <5k	22.0	22.2	23.8	19.0	25.2	17.0	30.8	16.6	29.1
	Medium 5-20k	19.3	23.5	17.6	24.1	15.0	22.5	16.8	15.6	13.5
	Large >20k	58.7	54.2	58.6	56.9	59.8	60.5	52.5	67.9	57.4

Notes:

a. Years comprise academic year; Fall and Spring
b. Only Fall

Table 2.2. Tobacco, Alcohol, and Marijuana Single-Product Use: Entire Sample, NCHA II, 2008-2015

		Overall	2008 [a]	2009 [a]	2010 [a]	2011 [a]	2012 [a]	2013 [a]	2014 [a]	2015 [b]	Slope Estimate [c]	SE	T-value	P-value	Percent Change [d]
Cigarettes	Occasional	8.0	9.5	8.3	8.7	8.2	7.8	7.4	6.8	5.9	-	-	-	-	-
	Frequent	5.3	7.0	6.3	6.3	5.3	5.2	4.3	3.4	3.1	-	-	-	-	-
	Current	13.3	16.4	14.6	15.0	13.4	13.0	11.6	10.1	9.0	-0.009	0.0002	-42.84	<0.001	-5.3
	Lifetime	28.3	33.0	30.5	30.6	28.7	27.6	25.8	23.4	20.4	-0.015	0.0003	-49.71	<0.001	-9.6
Hookah	Occasional	8.4	9.0	8.2	9.1	8.3	8.3	8.9	8.8	5.2	-	-	-	-	-
	Frequent	1.0	1.0	0.9	1.1	0.9	0.9	1.2	1.2	0.7	-	-	-	-	-
	Current	9.4	10.0	9.1	9.3	9.2	10.2	10.0	8.5	5.9	0.0006	0.0002	-3.14	0.002	-1.5
	Lifetime	32.7	33.0	32.0	33.0	33.8	34.2	33.7	30.8	23.3	-0.0006	0.0003	-2.22	0.03	-2.2
Cigars	Occasional	6.1	7.6	6.8	6.4	6.5	5.8	5.7	4.4	4.5	-	-	-	-	-
	Frequent	0.7	0.9	0.8	0.8	0.6	0.7	0.6	0.6	0.5	-	-	-	-	-
	Current	6.8	8.5	7.6	7.2	7.1	6.4	6.4	5.0	5.0	-0.005	0.0002	-29.78	<0.001	-3.5
	Lifetime	25.6	29.4	27.9	26.9	26.6	24.7	24.6	20.4	17.9	-0.013	0.0003	-44.39	<0.001	-9.0
Smokeless	Occasional	2.5	2.2	2.3	2.4	2.2	2.6	3.3	2.5	1.3	-	-	-	-	-
	Frequent	1.6	1.6	1.9	1.7	1.6	1.6	1.8	1.4	1.2	-	-	-	-	-
	Current	4.0	3.8	4.1	4.0	3.8	4.1	5.1	3.9	2.5	0.0008	0.0001	6.04	0.001	+0.1
	Lifetime	11.3	10.7	10.9	11.0	11.0	11.3	13.1	11.9	7.4	0.0009	0.0002	8.98	<0.001	+1.2
E-cigarettes	Occasional	3.6	-	-	-	-	-	-	-	3.6	-	-	-	-	-
	Frequent	1.6	-	-	-	-	-	-	-	1.6	-	-	-	-	-
	Current	5.2	-	-	-	-	-	-	-	5.2	-	-	-	-	-
	Lifetime	16.6	-	-	-	-	-	-	-	16.6	-	-	-	-	-
Alcohol	Occasional	50.3	51.8	50.1	49.6	51.1	49.7	50.6	49.6	47.6	-	-	-	-	-
	Frequent	14.4	15.2	14.4	14.5	14.1	14.5	14.6	13.6	13.2	-	-	-	-	-
	Current	64.6	67.1	64.5	64.0	65.1	64.2	65.1	63.2	60.9	-0.003	0.0003	-11.09	<0.001	-3.9
	Lifetime	77.7	79.9	77.6	76.8	78.2	77.4	77.8	77.0	75.8	-0.003	0.0003	-10.56	<0.001	-2.9
Binge Drinking	Occasional	14.7	14.5	14.6	14.4	14.9	14.7	15.1	15.0	13.8	-	-	-	-	-
	Frequent	21.7	24.0	22.3	22.2	21.7	21.0	21.2	19.9	19.6	-	-	-	-	-
	Current	36.4	38.5	36.8	36.5	36.6	35.7	36.3	34.9	33.4	-0.003	0.0003	-9.38	<0.001	-3.6
	Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Marijuana	Occasional	11.8	10.9	11.1	11.6	11.5	11.8	12.6	12.7	11.6	-	-	-	-	-
	Frequent	6.2	5.6	5.9	6.2	5.8	6.4	6.7	6.8	6.0	-	-	-	-	-
	Current	18.0	16.5	17.0	17.7	17.3	18.3	19.3	19.6	17.6	0.005	0.0003	19.99	<0.001	+3.1
	Lifetime	36.7	35.0	35.1	36.0	36.3	36.9	38.3	39.5	35.5	0.007	0.0003	23.16	<0.001	+4.5

Notes:

a. Years comprise academic year; Fall and Spring
b. Only Fall
c. Slope estimates from Fall 2008-Spring 2014; does not include Fall 2015
d. 2008-2014
e. Sample sizes are entire, male, and female analytical samples

Figure 2.1. Current Tobacco Use in the Last 30 days among College Students, NCHA II (N=619,546)

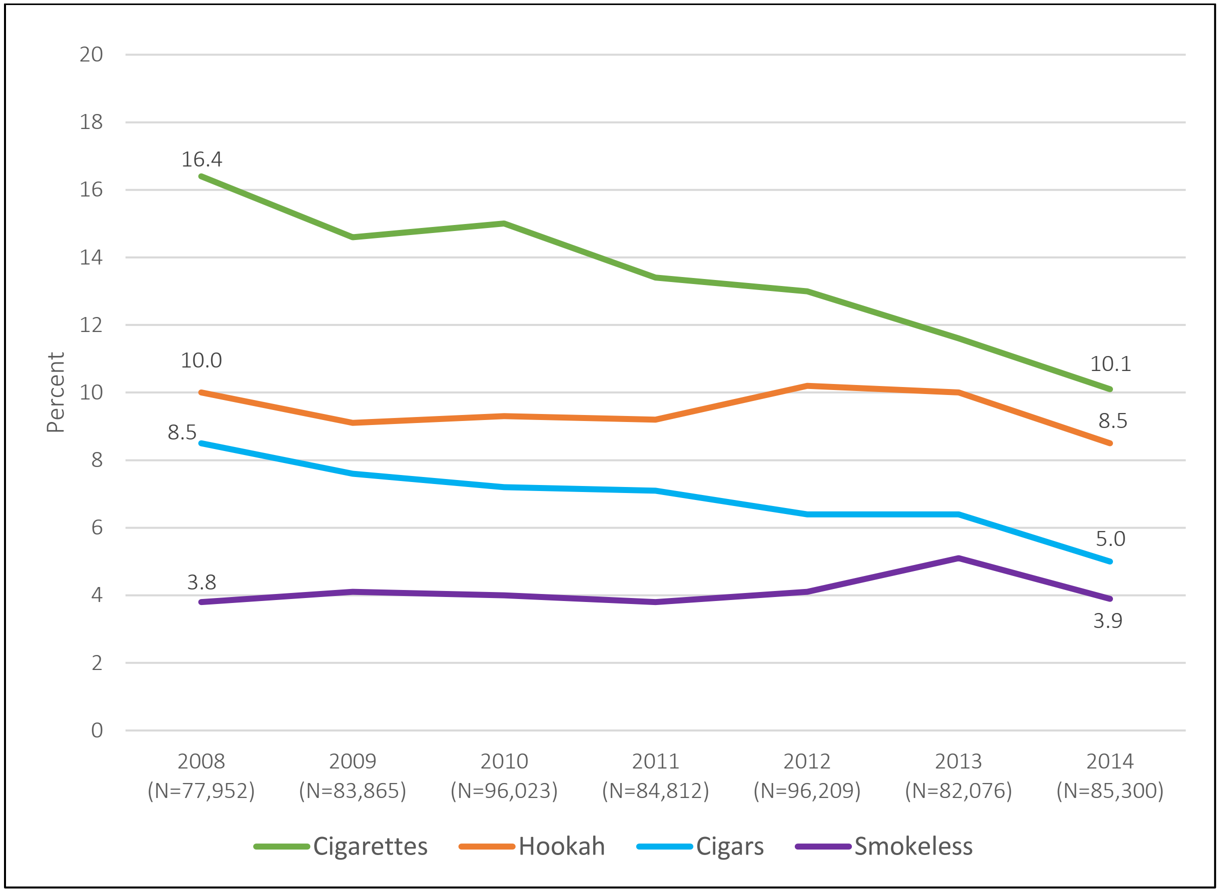


Figure 2.2. Lifetime Tobacco Use in the Last 30 days among College Students, NCHA II (N=619,546)

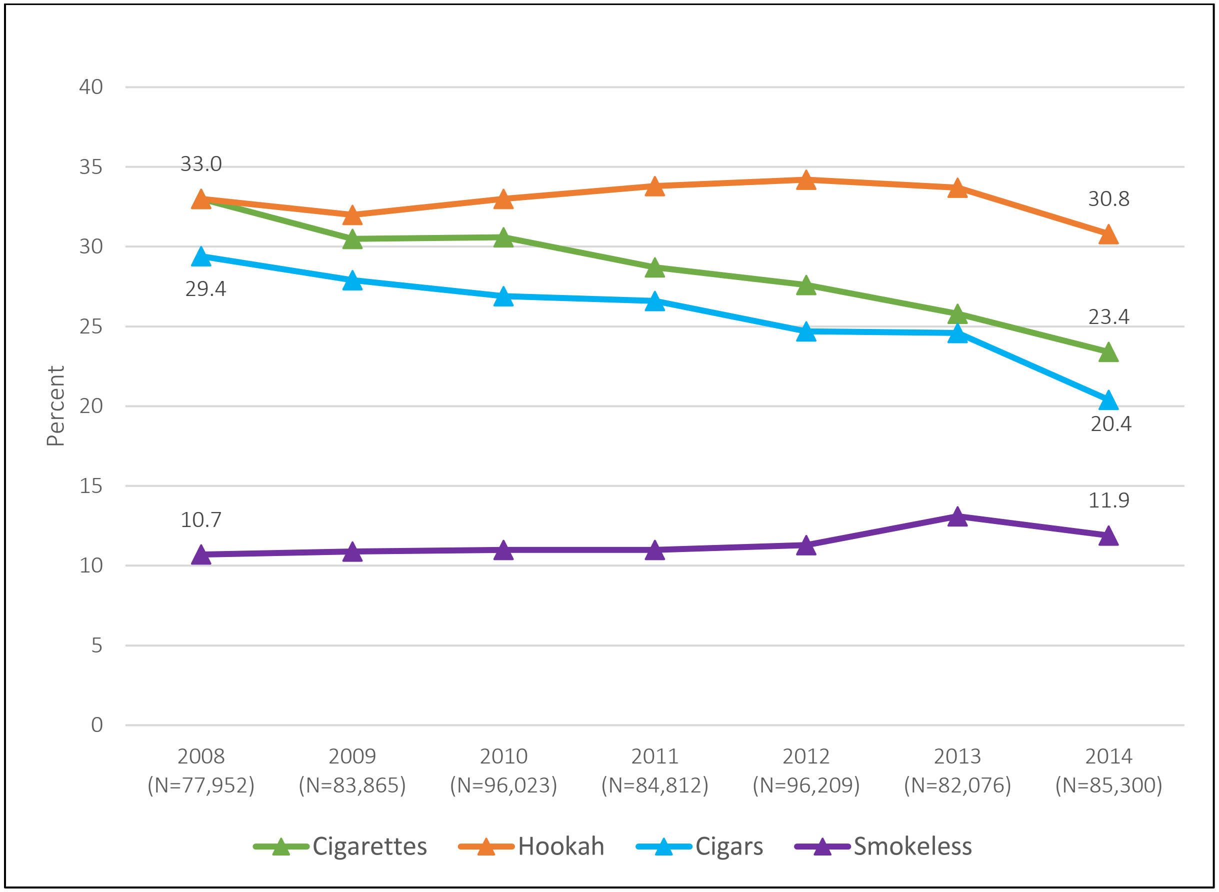


Table 2.3. Tobacco, Alcohol, and Marijuana Single-Product Use: Female Sample, NCHA II, 2008-2015

		Overall	2008 [a]	2009 [a]	2010 [a]	2011 [a]	2012 [a]	2013 [a]	2014 [a]	2015 [b]	Slope Estimate [c]	SE	T-value	P-value	Percent Changed
Cigarettes	Occasional	7.0	8.6	7.3	7.6	7.1	6.9	6.3	5.7	4.9	-	-	-	-	-
	Frequent	4.5	6.1	5.6	5.4	4.5	4.3	3.6	2.7	2.5	-	-	-	-	-
	Current	11.5	14.7	12.8	13.0	11.6	11.2	9.9	8.5	7.4	-0.009	0.0003	-36.84	<0.001	-6.2
	Lifetime	26.1	31.3	28.6	28.4	26.4	25.3	23.4	21.1	17.9	-0.016	0.0004	-44.84	<0.001	-10.2
Hookah	Occasional	7.3	7.7	6.9	7.3	7.2	8.0	7.9	6.6	4.8	-	-	-	-	-
	Frequent	0.8	0.7	0.7	0.7	0.7	1.0	0.9	1.0	0.6	-	-	-	-	-
	Current	8.1	8.4	7.5	8.0	7.9	9.0	8.8	7.6	5.4	0.0005	0.0002	2.16	0.03	-0.8
	Lifetime	30.6	30.5	29.4	31.0	31.6	32.1	31.6	29.3	22.0	0.0007	0.0004	1.93	0.05	-1.2
Cigars	Occasional	3.4	4.5	3.7	3.7	3.5	3.2	3.1	2.2	2.3	-	-	-	-	-
	Frequent	0.4	0.6	0.4	0.4	0.3	0.4	0.3	0.3	0.3	-	-	-	-	-
	Current	3.8	5.1	4.1	4.1	3.8	3.5	3.4	2.6	2.7	-0.012	0.0003	-38.66	<0.001	-2.5
	Lifetime	19.0	22.8	21.0	20.5	19.7	18.1	17.7	14.5	11.9	-0.013	0.0003	-42.18	<0.001	-8.3
Smokeless	Occasional	1.3	0.9	1.0	1.2	1.1	1.5	2.0	1.3	0.5	-	-	-	-	-
	Frequent	0.4	0.3	0.3	0.3	0.3	0.4	0.5	0.3	0.1	-	-	-	-	-
	Current	1.7	1.2	1.4	1.6	1.5	1.9	2.5	1.7	0.6	0.001	0.0001	13.21	<0.001	+0.5
	Lifetime	6.5	5.6	5.7	6.1	6.2	6.6	8.1	7.8	3.4	0.004	0.0002	20.89	<0.001	+2.2
E-cigarettes	Occasional	2.7	-	-	-	-	-	-	-	2.7	-	-	-	-	-
	Frequent	0.9	-	-	-	-	-	-	-	0.9	-	-	-	-	-
	Current	3.6	-	-	-	-	-	-	-	3.6	-	-	-	-	-
	Lifetime	13.3	-	-	-	-	-	-	-	13.3	-	-	-	-	-
Alcohol	Occasional	51.9	53.8	51.7	51.5	52.5	51.3	52.3	51.2	49.3	-	-	-	-	-
	Frequent	12.5	12.6	12.3	12.4	12.1	12.6	12.9	12.3	11.9	-	-	-	-	-
	Current	64.4	66.4	64.0	63.9	64.6	64.0	65.2	63.5	61.3	-0.002	0.0004	-5.64	<0.001	-2.9
	Lifetime	78.1	80.0	78.0	77.3	78.4	77.7	78.1	77.9	76.9	-0.002	0.0003	-6.32	<0.001	-2.1
Binge Drinking	Occasional	14.5	14.5	14.4	14.2	14.7	14.4	14.8	14.8	13.7	-	-	-	-	-
	Frequent	17.4	18.9	17.6	17.8	17.3	16.8	17.3	16.6	16.4	-	-	-	-	-
	Current	31.9	33.4	32.0	32.0	32.0	31.2	32.1	31.4	30.2	-0.002	0.0004	-6.03	<0.001	-3.0
	Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Marijuana	Occasional	11.3	10.4	10.4	11.2	11.0	11.4	12.2	12.3	11.2	-	-	-	-	-
	Frequent	4.6	4.0	4.3	4.5	4.2	4.8	4.9	5.4	4.9	-	-	-	-	-
	Current	15.9	14.3	14.8	15.7	15.2	16.1	17.1	17.7	16.1	0.005	0.0003	18.61	<0.001	+3.4
	Lifetime	34.8	32.9	32.9	34.1	34.3	34.7	36.2	37.9	34.2	0.008	0.0004	20.81	<0.001	+5.0

Notes:

a. Years comprise academic year; Fall and Spring
b. Only Fall
c. Slope estimates from Fall 2008-Spring 2014; does not include Fall 2015
d. 2008-2014
e. Sample sizes are female analytical sample

Figure 2.3. Current Tobacco Use in the Last 30 days among Female College Students, NCHA II (N= 415,715)

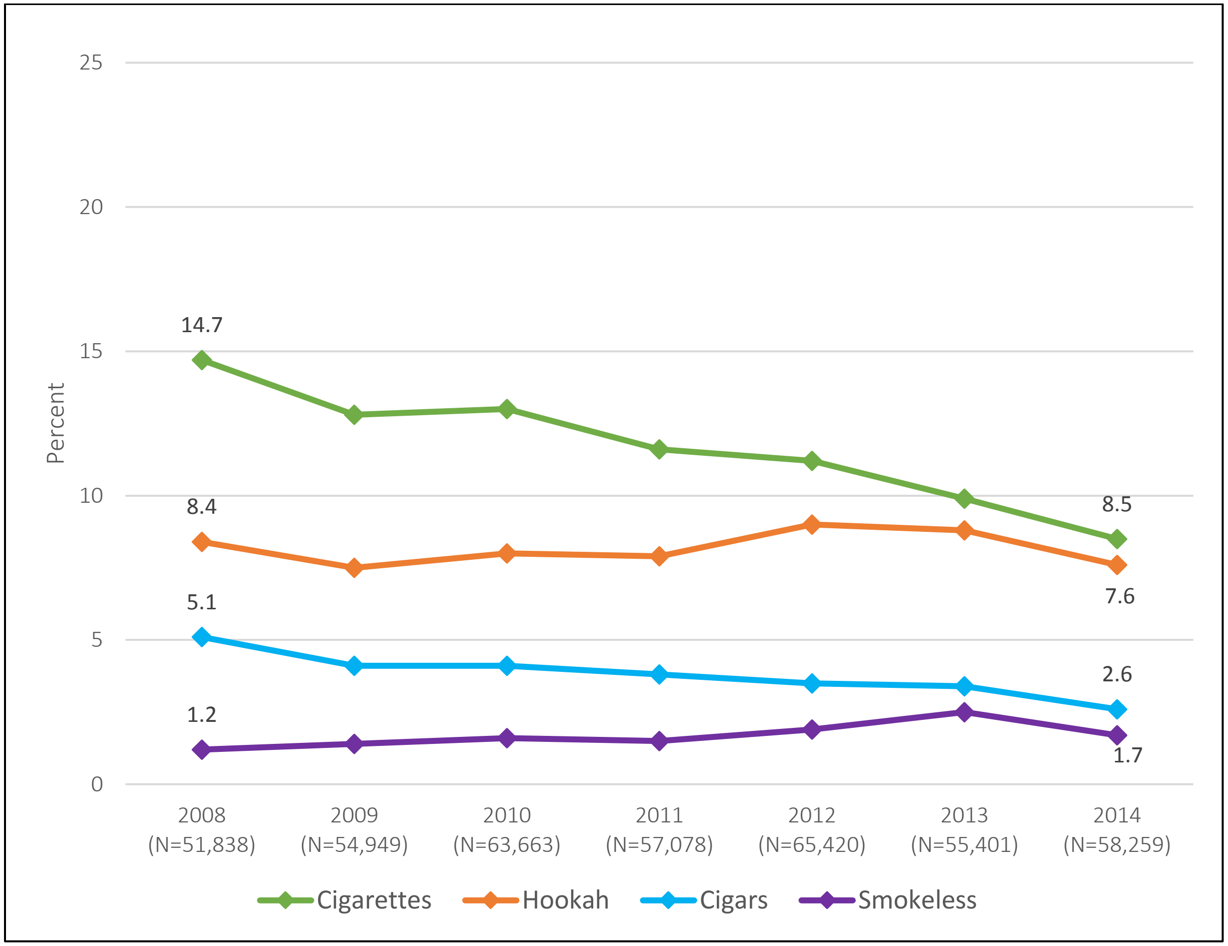


Table 2.4. Tobacco, Alcohol, and Marijuana Single-Product Use: Male Sample, NCHA II, 2008-2015

		Overall	2008[a]	2009[a]	2010[a]	2011[a]	2012[a]	2013[a]	2014[a]	2015[b]	Slope Estimate[c]	SE	T-value	P-value	Percent Change[d]
Cigarettes	Occasional	7.0	8.6	7.3	7.6	7.1	6.9	6.3	5.7	4.9	-	-	-	-	-
	Frequent	4.5	6.1	5.6	5.4	4.5	4.3	3.6	2.7	2.5	-	-	-	-	-
	Current	11.5	14.7	12.8	13.0	11.6	11.2	9.9	8.5	7.4	-0.009	0.0003	-36.84	<0.001	-6.2
	Lifetime	26.1	31.3	28.6	28.4	26.4	25.3	23.4	21.1	17.9	-0.016	0.0004	-44.84	<0.001	-10.2
Hookah	Occasional	7.3	7.7	6.9	7.3	7.2	8.0	7.9	6.6	4.8	-	-	-	-	-
	Frequent	0.8	0.7	0.7	0.7	0.7	1.0	0.9	1.0	0.6	-	-	-	-	-
	Current	8.1	8.4	7.5	8.0	7.9	9.0	8.8	7.6	5.4	0.0005	0.0002	2.16	0.03	-0.8
	Lifetime	30.6	30.5	29.4	31.0	31.6	32.1	31.6	29.3	22.0	0.0007	0.0004	1.93	0.05	-1.2
Cigars	Occasional	3.4	4.5	3.7	3.7	3.5	3.2	3.1	2.2	2.3	-	-	-	-	-
	Frequent	0.4	0.6	0.4	0.4	0.3	0.4	0.3	0.3	0.3	-	-	-	-	-
	Current	3.8	5.1	4.1	4.1	3.8	3.5	3.4	2.6	2.7	-0.012	0.0003	-38.66	<0.001	-2.5
	Lifetime	19.0	22.8	21.0	20.5	19.7	18.1	17.7	14.5	11.9	-0.013	0.0003	-42.18	<0.001	-8.3
Smokeless	Occasional	1.3	0.9	1.0	1.2	1.1	1.5	2.0	1.3	0.5	-	-	-	-	-
	Frequent	0.4	0.3	0.3	0.3	0.3	0.4	0.5	0.3	0.1	-	-	-	-	-
	Current	1.7	1.2	1.4	1.6	1.5	1.9	2.5	1.7	0.6	0.001	0.0001	13.21	<0.001	+0.5
	Lifetime	6.5	5.6	5.7	6.1	6.2	6.6	8.1	7.8	3.4	0.004	0.0002	20.89	<0.001	+2.2
E-cigarettes	Occasional	2.7	-	-	-	-	-	-	-	2.7	-	-	-	-	-
	Frequent	0.9	-	-	-	-	-	-	-	0.9	-	-	-	-	-
	Current	3.6	-	-	-	-	-	-	-	3.6	-	-	-	-	-
	Lifetime	13.3	-	-	-	-	-	-	-	13.3	-	-	-	-	-
Alcohol	Occasional	51.9	53.8	51.7	51.5	52.5	51.3	52.3	51.2	49.3	-	-	-	-	-
	Frequent	12.5	12.6	12.3	12.4	12.1	12.6	12.9	12.3	11.9	-	-	-	-	-
	Current	64.4	66.4	64.0	63.9	64.6	64.0	65.2	63.5	61.3	-0.002	0.0004	-5.64	<0.001	-2.9
	Lifetime	78.1	80.0	78.0	77.3	78.4	77.7	78.1	77.9	76.9	-0.002	0.0003	-6.32	<0.001	-2.1
Binge Drinking	Occasional	14.5	14.5	14.4	14.2	14.7	14.4	14.8	14.8	13.7	-	-	-	-	-
	Frequent	17.4	18.9	17.6	17.8	17.3	16.8	17.3	16.6	16.4	-	-	-	-	-
	Current	31.9	33.4	32.0	32.0	32.0	31.2	32.1	31.4	30.2	-0.002	0.0004	-6.03	<0.001	-3.0
	Lifetime	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Marijuana	Occasional	11.3	10.4	10.4	11.2	11.0	11.4	12.2	12.3	11.2	-	-	-	-	-
	Frequent	4.6	4.0	4.3	4.5	4.2	4.8	4.9	5.4	4.9	-	-	-	-	-
	Current	15.9	14.3	14.8	15.7	15.2	16.1	17.1	17.7	16.1	0.005	0.0003	18.61	<0.001	+3.4
	Lifetime	34.8	32.9	32.9	34.1	34.3	34.7	36.2	37.9	34.2	0.008	0.0004	20.81	<0.001	+5.0

Notes:

a. Years comprise academic year; Fall and Spring
b. Fall only
c. Slope estimates from Fall 2008-Spring 2014; does not include Fall 2015
d. 2008-2014
e. Sample sizes are male analytical sample

Figure 2.4. Current Tobacco Use in the Last 30 days among Male College Students, NCHA II (N= 208,831)

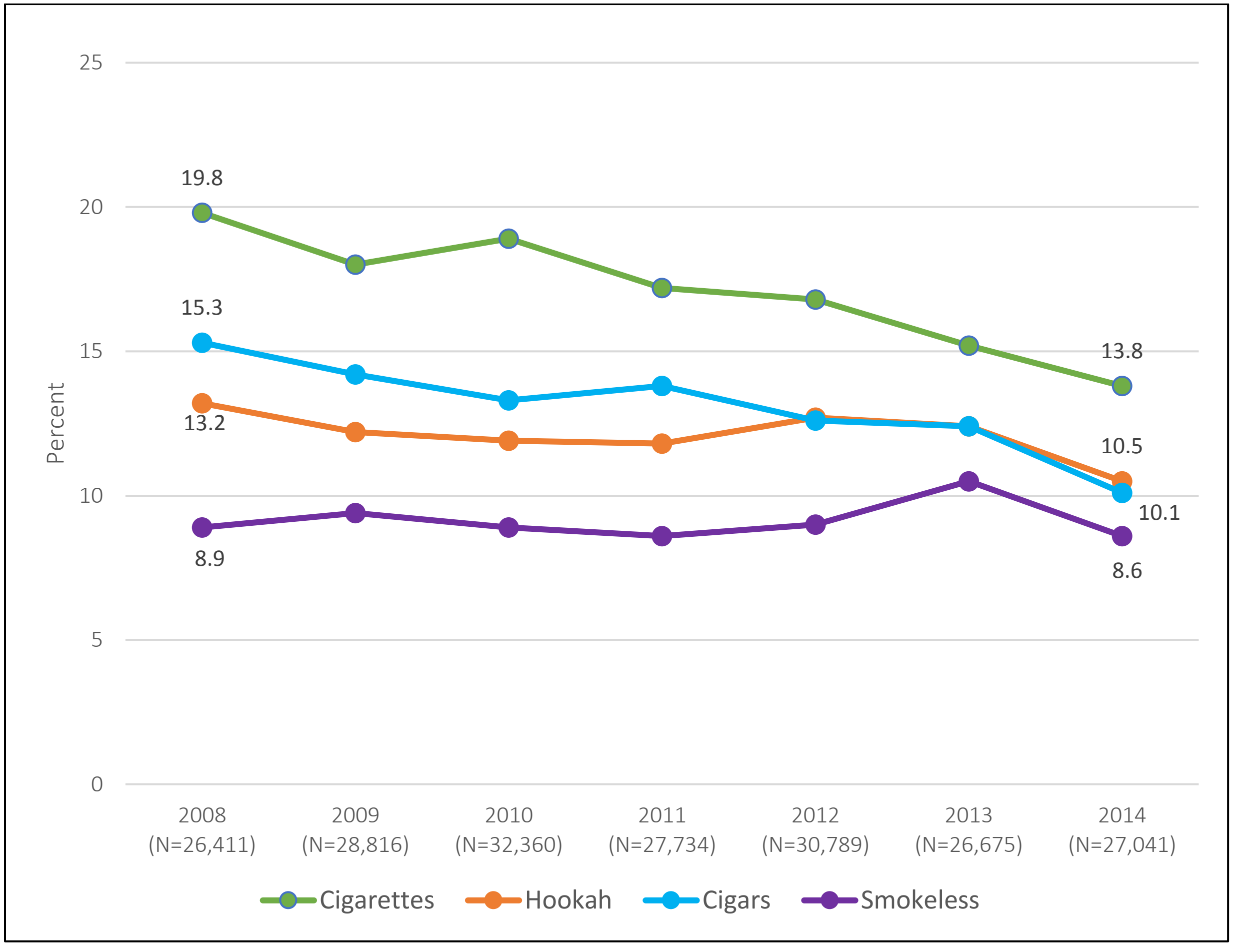


Table 2.5. Prevalence of Polytobacco Use and Average Number of Behaviors and Perceived Peer Behaviors Used, NCHA II, 2008-2015

	Overall	2008[a]	2009[a]	2010[a]	2011[a]	2012[a]	2013[a]	2014[a]	2015[b]	Slope Estimate[c]	SE	T-value	P-value
Entire Sample[d]													
0	77.4	74.4	76.3	76.1	77.5	77.3	78.1	81.3	82.4				
1	14.6	16.2	15.1	15.6	14.5	14.8	14.1	12.4	10.9	-0.005	0.0002	-21.91	<0.001
2+	8.2	9.4	8.5	8.4	8.0	7.9	7.9	6.3	6.8	-0.004	0.0002	-23.36	<0.001
Average Used (SD)	0.34	0.39	0.35	0.35	0.33	0.34	0.33	0.27	0.28				
	(0.72)	(0.76)	(0.73)	(0.72)	(0.71)	(0.71)	(0.72)	(0.66)	(0.70)				
Average Perceived	2.80	2.83	2.78	2.80	2.73	2.81	2.73	2.78	3.49				
Peers Used (SD)	(1.47)	(1.38)	(1.44)	(1.43)	(1.47)	(1.44)	(1.52)	(1.51)	(1.88)				
Females[d]													
0	81.5	78.7	80.9	80.3	81.8	81.2	82.1	84.9	86.2				
1	13.3	15.0	13.8	14.4	13.0	13.6	12.8	11.1	9.5	-0.005	0.0003	-19.32	<0.001
2+	5.4	6.2	5.4	5.4	5.1	5.3	5.2	4.0	4.4	-0.003	0.0002	-15.14	<0.001
Average Used (SD)	0.25	0.29	0.26	0.27	0.25	0.25	0.25	0.20	0.20				
	(0.59)	(0.64)	(0.59)	(0.60)	(0.59)	(0.60)	(0.60)	(0.54)	(0.56)				
Average Perceived	2.85	2.87	2.84	2.85	2.77	2.86	2.79	2.85	3.59				
Peers Used (SD)	(1.43)	(1.35)	(1.39)	(1.39)	(1.43)	(1.40)	(1.48)	(1.47)	(1.82)				
Males[d]													
0	69.0	65.8	67.7	67.8	68.7	68.9	69.8	73.7	74.0				
1	17.3	18.4	17.7	17.9	17.6	17.5	16.9	15.2	14.0	-0.004	0.0004	-9.78	<0.001
2+	14.2	15.8	14.7	14.3	13.8	13.6	13.4	11.1	11.9	-0.006	0.0004	-15.49	<0.001
Average Used (SD)	0.51	0.57	0.54	0.53	0.51	0.51	0.50	0.43	0.45				
	(0.90)	(0.93)	(0.91)	(0.90)	(0.89)	(0.89)	(0.90)	(0.84)	(0.91)				
Average Perceived	2.69	2.76	2.69	2.70	1.64	2.71	2.62	2.62	3.27				
Peers Used (SD)	(1.54)	(1.44)	(1.50)	(1.50)	(1.54)	(1.52)	(1.58)	(1.58)	(1.98)				

Notes:

a. Years comprise academic year; Fall and Spring
b. Fall only
c. Slope estimates from Fall 2008-Spring 2014; does not include Fall 2015
d. Proportions of the number of behaviors significantly different between genders
e. Sample sizes are entire, male, and female analytical samples

Figure 2.5. College Student Current Single-product and Polytobacco Use, Last 30 days, NCHA II

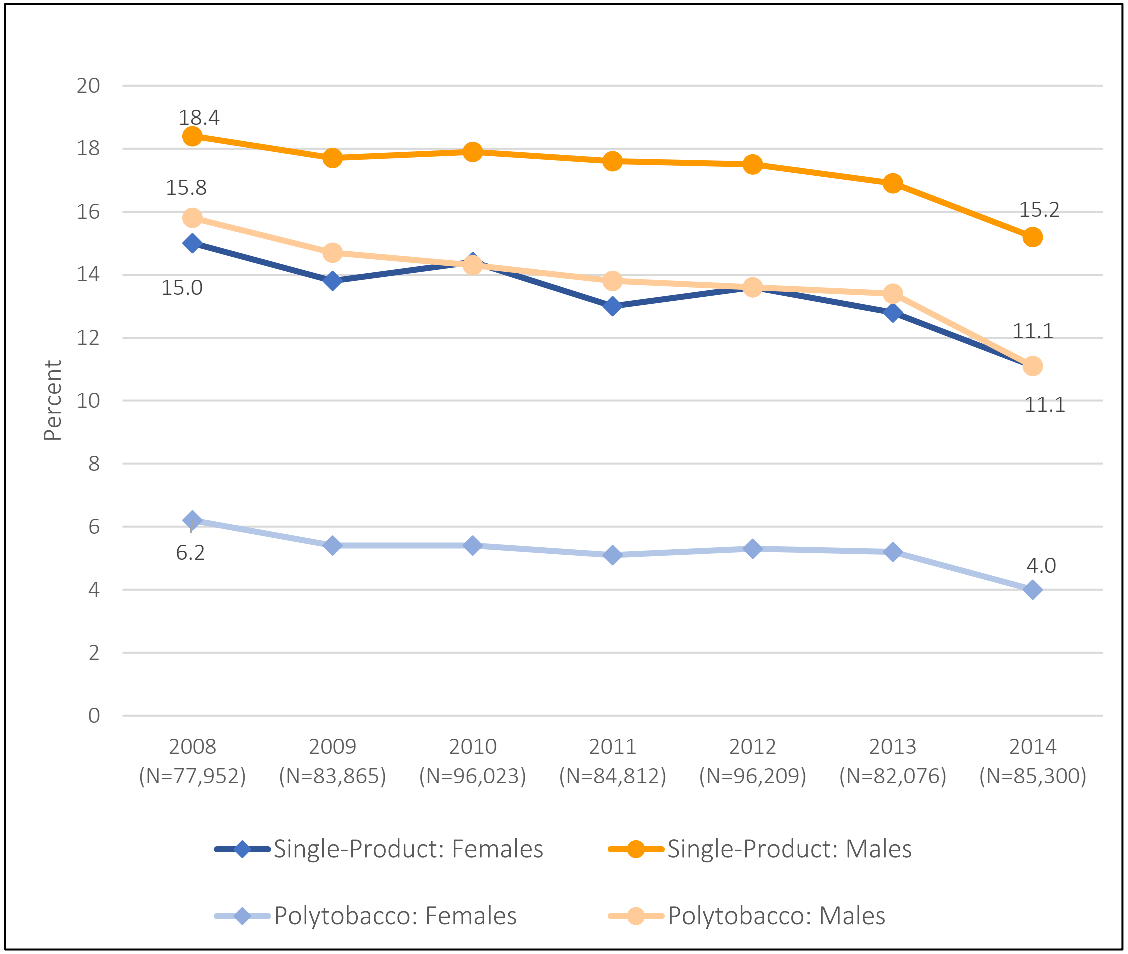


Table 2.6. Prevalence and Trends of Polytobacco Use with Single-Products, NCHA II, 2008-2015

		Overall	2008[a]	2009[a]	2010[a]	2011[a]	2012[a]	2013[a]	2014[a]	2015[b]	Slope Estimate[c]	SE	T-value	P-value
Polytobacco Use with Cigarettes	Entire Sample	6.5	8.0	7.1	7.0	6.5	6.3	6.0	4.9	5.0	-0.004	0.0002	-26.68	<0.001
	Females	4.5	5.7	4.8	4.8	4.4	4.5	4.2	3.3	3.3	-0.003	0.0002	-18.00	<0.001
	Males	10.6	12.6	11.6	11.4	10.8	10.3	9.8	8.3	8.7	-0.006	0.0003	-17.82	<0.001
Polytobacco Use with Hookah	Entire Sample	5.2	6.5	8.0	7.1	7.0	6.5	6.3	6.0	4.9	-0.002	0.0001	-13.03	<0.001
	Females	3.8	4.4	3.7	3.9	3.8	4.0	3.7	3.1	2.5	-0.001	0.0002	-8.83	<0.001
	Males	8.1	9.2	8.3	8.2	8.1	8.4	8.3	6.8	4.9	-0.003	0.0003	-7.96	<0.001
Polytobacco Use with Cigars	Entire Sample	4.7	6.0	5.3	5.0	4.8	4.4	4.3	3.3	3.2	-0.004	0.0001	-26.94	<0.001
	Females	2.6	3.6	2.9	2.8	2.7	2.4	2.3	1.7	1.6	-0.003	0.0001	-20.57	<0.001
	Males	9.0	10.7	9.9	9.4	9.3	8.7	8.5	6.9	6.7	-0.005	0.0003	-16.04	<0.001
Polytobacco Use with Smokeless	Entire Sample	2.7	2.5	2.6	2.5	2.4	2.7	3.4	2.6	1.7	0.0007	0.0001	6.39	<0.001
	Females	1.0	0.7	0.7	0.8	0.8	1.1	1.6	1.1	0.5	0.001	0.0001	15.01	<0.001
	Males	6.1	6.0	6.3	5.9	5.7	6.2	7.0	5.7	4.5	0.0003	0.0003	0.97	0.33
Polytobacco Use with E-cigarettes	Entire Sample	5.2	-	-	-	-	-	-	-	5.2	-	-	-	-
	Females	3.6	-	-	-	-	-	-	-	3.6	-	-	-	-
	Males	8.9	-	-	-	-	-	-	-	8.9	-	-	-	-

Notes:

a. Years comprise academic year; Fall and Spring
b. Fall only
c. Slope estimates from Fall 2008-Spring 2014; does not include Fall 2015
d. All prevalence rates were significantly different between genders
e. Sample sizes are entire, male, and female analytical samples

Table 2.7. Use of Tobacco Products among Polytobacco Users, NCHA II, 2008-2015

	Overall	2008[a]	2009[a]	2010[a]	2011[a]	2012[a]	2013[a]	2014[a]	2015[b]	Slope Estimate[c]	SE	T-value	P-value
Entire Sample	N=51,036	n=7,454	n=7,314	n=8,219	n=6,911	n=7,814	n=6,533	n=5,839	n=952				
Cigarette Smoking	81.3	84.6	83.0	83.5	81.9	79.8	77.5	78.0	74.6	-0.012	0.001	-13.65	<0.001
Hookah Use	65.1	63.5	62.2	63.8	65.5	68.7	67.0	67.6	47.9	0.010	0.001	8.95	<0.001
Cigar Use	58.5	63.4	61.8	59.7	60.6	55.5	55.3	53.2	47.3	-0.017	0.001	-14.77	<0.001
Smokeless Tobacco Use	33.1	26.1	30.8	30.3	30.3	34.4	43.2	41.0	25.8	-0.026	0.001	23.66	<0.001
E-cigarette Use	52.8	-	-	-	-	-	-	-	52.8	-	-	-	-
Females	N=22,456	n=3,302	n=3,032	n=3,519	n=3,038	n=3,550	n=2,919	n=2,669	n=427				
Cigarette Smoking	86.3	90.2	88.9	88.2	86.3	85.0	82.7	82.8	77.2	-0.014	0.001	-11.28	<0.001
Hookah Use	72.8	69.6	69.7	72.3	73.8	76.8	73.6	75.9	57.1	0.012	0.002	7.28	<0.001
Cigar Use	49.2	57.2	53.3	51.1	51.5	45.1	44.2	41.7	36.0	-0.025	0.002	-14.40	<0.001
Smokeless Tobacco Use	18.6	10.8	12.9	15.3	15.9	20.9	31.3	27.3	10.7	0.033	0.001	23.98	<0.001
E-cigarette Use	53.6	-	-	-	-	-	-	-	53.6	-	-	-	-
Males	N=28,580	n=4,152	n=4,282	N=4,700	n=3,873	n=4,264	n=3,614	n=3,170	n=525				
Cigarette Smoking	77.4	80.2	78.9	80.1	78.5	75.6	73.4	74.3	72.6	-0.012	0.001	-9.17	<0.001
Hookah Use	59.1	58.6	56.8	57.5	59.1	62.0	61.9	61.1	40.6	0.008	0.001	5.31	<0.001
Cigar Use[1]	65.7	68.3	67.7	66.2	67.7	64.0	64.2	62.2	56.1	-0.010	0.002	-6.53	<0.001
Smokeless Tobacco Use	44.3	38.3	43.3	41.4	41.4	45.4	52.6	51.8	37.6	0.022	0.002	14.25	<0.001
E-cigarette Use	52.2	-	-	-	-	-	-	-	52.2	-	-	-	-

Notes:

a. Years comprise academic year; Fall and Spring
b. Fall only
c. Slope estimates from Fall 2008-Spring 2014; does not include Fall 2015
d. All prevalence rates were significantly different between genders

Table 2.8. Prevalence of Perceived Peer Tobacco and Substance use, NCHA II, 2008-2015

		Overall	2008[a]	2009[a]	2010[a]	2011[a]	2012[a]	2013[a]	2014[a]	2015[b]	Slope Estimate[c]	SE	T-value	P-value	Percent Change[d]
Cigarettes	Entire Sample	81.7	85.4	83.2	84.0	81.5	83.0	77.9	77.5	76.9	-0.013	0.00023	-49.46	<0.001	-7.9
	Females	83.5	87.0	85.1	85.9	83.4	84.7	79.9	79.4	79.5	-0.012	0.0003	-41.16	<0.001	-7.6
	Males	77.9	82.3	79.6	80.2	77.5	79.3	73.8	73.4	71.2	-0.014	0.0005	-29.30	<0.001	-8.9
Hookah	Entire Sample	72.4	72.6	70.3	72.4	71.2	74.4	71.6	74.1	71.5	0.004	0.0003	11.88	<0.001	+1.5
	Females	74.6	74.4	72.3	74.6	73.2	76.5	73.9	76.8	74.5	0.005	0.0004	13.29	<0.001	+2.4
	Males	67.9	69.1	66.3	68.1	67.1	69.9	66.8	68.3	64.9	0.0003	0.0005	0.62	0.54	-0.8
Cigars	Entire Sample	65.5	68.9	67.4	66.7	64.4	66.0	63.2	62.4	62.2	-0.010	0.0003	-32.63	<0.001	-6.5
	Females	66.3	69.6	68.1	67.5	64.9	66.7	64.0	63.6	63.7	-0.010	0.0004	-24.82	<0.001	-6.0
	Males	64.0	67.7	66.1	65.2	63.5	64.5	61.4	59.7	59.1	-0.012	0.0006	-21.93	<0.001	-8.0
Smokeless	Entire Sample	60.5	58.8	59.9	58.8	57.8	60.1	62.5	65.3	63.0	0.009	0.0003	29.22	<0.001	+6.5
	Females	61.0	58.7	60.5	59.2	58.0	60.4	63.0	66.5	64.2	0.001	0.0001	13.21	<0.001	+7.8
	Males	59.5	58.9	58.7	58.1	57.3	59.5	61.3	62.8	60.3	0.0005	0.0003	1.61	0.10	+3.9
E-cigarettes	Entire Sample	76.4	-	-	-	-	-	-	-	76.4	-	-	-	-	-
	Females	78.2	-	-	-	-	-	-	-	78.2	-	-	-	-	-
	Males	72.4	-	-	-	-	-	-	-	72.4	-	-	-	-	-
Alcohol	Entire Sample	95.1	96.2	95.5	95.0	95.6	94.8	95.5	93.6	93.9	-0.003	0.0001	-19.86	<0.001	-2.6
	Females	95.8	96.7	96.1	95.9	96.3	95.5	96.2	94.2	94.3	-0.003	0.0002	-17.51	<0.001	-2.3
	Males	93.7	95.0	94.2	93.2	94.1	93.3	94.0	92.1	92.9	-0.003	0.0003	-11.05	<0.001	-2.9
Marijuana	Entire Sample	83.5	81.8	81.7	83.2	83.0	84.8	84.8	84.8	86.0	0.006	0.0002	24.63	<0.001	+3.0
	Females	85.1	83.3	83.4	85.1	84.4	86.1	86.4	86.3	87.4	0.006	0.0003	19.74	<0.001	+3.0
	Males	80.4	79.0	78.4	79.4	80.2	81.9	81.6	81.7	82.9	0.006	0.0004	13.53	<0.001	+2.7

Notes:

a. Years comprise academic year; Fall and Spring
b. Fall only
c. Slope estimates from Fall 2008-Spring 2014; does not include Fall 2015
d. 2008-2014
e. Sample sizes are entire, male, and female analytical samples

Table 2.9. Relationship between Perceived Peer Tobacco and Substance use and Self-Reported Substance use, NCHA II 2008-2014

		aOR	Overall 95% CI	p-value
Cigarettes	Entire Sample	**2.04**	**2.00-2.09**	**<0.001**
	Females	**2.16**	**2.09-2.23**	**<0.001**
	Males	**2.12**	**2.05-2.20**	**<0.001**
Hookah	Entire Sample	**2.95**	**2.87-3.02**	**<0.001**
	Females	**3.33**	**3.20-3.44**	**<0.001**
	Males	**2.84**	**2.73-2.94**	**<0.001**
Cigars	Entire Sample	**2.23**	**2.17-2.29**	**<0.001**
	Females	**2.48**	**2.37-2.58**	**<0.001**
	Males	**2.30**	**2.23-2.37**	**<0.001**
Smokeless	Entire Sample	**2.76**	**2.68-2.86**	**<0.001**
	Females	**2.11**	**2.00-2.24**	**<0.001**
	Males	**3.32**	**3.20-3.45**	**<0.001**
E-cigarettes	Entire Sample	**2.20**	**1.76-2.77**	**<0.001**
	Females	**2.43**	**1.70-3.48**	**<0.001**
	Males	**2.41**	**1.79-3.25**	**<0.001**
Alcohol	Entire Sample	**8.76**	**8.50-9.02**	**<0.001**
	Females	**9.26**	**8.90-9.65**	**<0.001**
	Males	**8.20**	**7.85-8.58**	**<0.001**
Marijuana	Entire Sample	**3.62**	**3.53-3.72**	**<0.001**
	Females	**3.96**	**3.82-4.11**	**<0.001**
	Males	**3.61**	**3.48-3.75**	**<0.001**

Notes:
a. Adjusted for study year, institution ID, and age
b. Items in bold are significant

Table 2.10. Relationship between Student/Institutional Characteristics and Substance Use and Polytobacco Behaviors among Females, NCHA II, 2008-2014

		Polytobacco Use with Cigarettes			**Polytobacco Use with Hookah**			**Polytobacco Use with Cigar**			**Polytobacco Use with Smokeless Tobacco**		
		aOR	**95% CI**	**p-value**	**aOR**	**95% CI**	**p-value**	**aOR**	**95% CI**	**p-value**	**aOR**	**95% CI**	**p-value**
Race	White (ref)	-	-	-	-	-	-	-	-	-	-	-	-
	Black	**0.43**	**0.39-0.46**	**<0.001**	**0.47**	**0.43-0.52**	**<0.001**	**0.64**	**0.58-0.71**	**<0.001**	**0.56**	**0.46-0.67**	**<0.001**
	Hispanic	**0.67**	**0.63-0.71**	**<0.001**	**0.71**	**0.67-0.76**	**<0.001**	**0.54**	**0.50-0.59**	**<0.001**	0.74	0.65-0.84	0.005
	Asian	**1.00**	**0.95-1.05**	**<0.001**	**1.03**	**0.98-1.09**	**<0.001**	0.88	0.82-0.94	0.08	0.94	0.84-1.05	0.07
	Other	**1.31**	**1.25-1.38**	**<0.001**	**1.35**	**1.28-1.43**	**<0.001**	**1.30**	**1.22-1.39**	**<0.001**	**1.23**	**1.11-1.37**	**<0.001**
Sexual Orientation	Heterosexual (ref)	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Heterosexual	**2.66**	**2.56-2.77**	**<0.001**	**2.33**	**2.23-2.44**	**<0.001**	**2.68**	**2.55-2.83**	**<0.001**	**2.18**	**2.00-2.37**	**<0.001**
Lives:	On-campus (ref)	-	-	-	-	-	-	-	-	-	-	-	-
	Off-campus	**1.18**	**1.15-1.22**	**<0.001**	**1.18**	**1.14-1.22**	**<0.001**	**1.09**	**1.04-1.14**	**<0.001**	**1.23**	**1.15-1.32**	**<0.001**
Year in School	1st (ref)	-	-	-	-	-	-	-	-	-	-	-	-
	2nd	**0.99**	**0.95-1.04**	**<0.001**	1.05	1.00-1.10	0.05	0.95	0.90-1.01	0.46	0.83	0.75-0.91	0.26
	3rd	0.95	0.89-1.00	0.12	0.99	0.93-1.06	0.001	0.93	0.86-1.00	0.89	0.80	0.71-0.90	0.78
	4th	**0.85**	**0.79-0.92**	**<0.001**	0.89	0.82-0.97	0.03	**0.84**	**0.76-0.93**	**<0.001**	**0.66**	**0.57-0.77**	**<0.001**
	5th	0.84	0.74-0.94	0.01	0.87	0.77-1.00	0.34	0.94	0.81-1.10	0.85	0.72	0.58-0.90	0.16
Participates in a Greek organization	Yes	1.04	0.99-1.09	0.10	**1.11**	**1.06-1.17**	**<0.001**	0.97	0.91-1.03	0.26	1.10	1.01-1.20	0.03
	No (ref)	-	-	-	-	-	-	-	-	-	-	-	-
Approx. GPA	A (ref)	-	-	-	-	-	-	-	-	-	-	-	-
	B	**1.65**	**1.59-1.71**	**<0.001**	**1.63**	**1.57-1.69**	**<0.001**	**1.61**	**2.14-1.69**	**<0.001**	1.79	1.66-1.93	0.02
	C	**2.25**	**2.15-2.36**	**<0.001**	**2.10**	**1.99-2.21**	**<0.001**	**2.35**	**2.21-2.50**	**<0.001**	**2.55**	**2.30-2.81**	**<0.001**
	D/F	**3.28**	**2.86-3.76**	**<0.001**	**2.93**	**2.52-3.41**	**<0.001**	**3.31**	**2.78-3.94**	**<0.001**	**3.35**	**2.51-4.46**	**<0.001**
Region	Northeast (ref)	-	-	-	-	-	-	-	-	-	-	-	-
	Midwest	0.89	0.85-0.93	0.001	0.94	0.89-0.98	0.004	0.99	0.93-1.04	0.93	1.13	1.03-1.24	0.03
	South	0.94	0.91-0.98	0.40	0.96	0.92-1.00	0.12	1.03	0.98-1.08	0.008	0.98	0.90-1.06	0.003
	West	0.90	0.87-0.94	0.01	1.02	0.98-1.07	0.002	0.93	0.88-0.99	0.002	1.13	1.04-1.24	0.01
Inst. Type	Public (ref)	-	-	-	-	-	-	-	-	-	-	-	-
	Private	1.01	0.98-1.05	0.38	0.98	0.95-1.01	0.20	**0.90**	**0.87-0.94**	**<0.001**	**0.83**	**0.77-0.88**	**<0.001**
Campus Size	Small <5k (ref)	-	-	-	-	-	-	-	-	-	-	-	-
	Medium 5-20k	**0.91**	**0.87-0.96**	**<0.001**	**1.00**	**0.95-1.05**	**<0.001**	0.89	0.84-0.95	0.008	0.95	0.86-1.05	0.08
	Large >20k	1.01	0.97-1.05	0.001	**1.18**	**1.13-1.22**	**<0.001**	0.92	0.87-0.96	0.11	1.05	0.97-1.13	0.03
Current Alcohol Use		**11.06**	**10.37-11.79**	**<0.001**	**12.17**	**11.32-13.08**	**<0.001**	**10.09**	**9.30-10.95**	**<0.001**	**6.97**	**6.15-7.89**	**<0.001**
Current Binge Drinking		**5.30**	**5.14-5.48**	**<0.001**	**5.26**	**5.08-5.45**	**<0.001**	**4.69**	**4.50-4.88**	**<0.001**	**4.96**	**4.63-5.31**	**<0.001**
Current Marijuana Use		**9.05**	**8.78-9.34**	**<0.001**	**8.97**	**8.68-9.28**	**<0.001**	**8.15**	**7.83-8.49**	**<0.001**	**6.13**	**5.75-6.54**	**<0.001**
Perceived Peer Tobacco Use	0 (ref)	-	-	-	-	-	-	-	-	-	-	-	-
	1	**1.58**	**1.45-1.71**	**<0.001**	**1.59**	**1.44-1.75**	**<0.001**	**1.33**	**1.19-1.49**	**<0.001**	1.19	1.00-1.43	0.10
	2	**2.33**	**2.16-2.51**	**<0.001**	**2.53**	**2.32-2.75**	**<0.001**	**1.64**	**1.47-1.82**	**<0.001**	1.41	1.20-1.67	0.31
	3	**2.91**	**2.70-3.12**	**<0.001**	**3.22**	**2.91-3.50**	**<0.001**	**2.85**	**2.59-3.13**	**<0.001**	**1.93**	**1.66-2.24**	**<0.001**
	4	**2.39**	**2.23-2.55**	**<0.001**	**2.75**	**2.54-2.97**	**<0.001**	**2.49**	**2.28-2.72**	**<0.001**	**2.53**	**2.22-2.90**	**<0.001**
	5	2.26	1.91-2.68	0.04	2.09	1.73-2.52	0.80	2.30	1.83-2.90	<0.001	**0.68**	**0.45-1.04**	**<0.001**

Notes:

a. Adjusted for study year, institution ID, and age
b. Multiple comparisons corrections: 13 variables, 4 polytobacco use groups, at 0.05. Resulting significance level=0.001
c. Items in bold are significant
d. Sample sizes are the entire analytical female sample

Table 2.11: Relationship between Student/Institutional Characteristics and Substance Use and Polytobacco Behaviors among Males, NCHA II, 2008-2014

		Polytobacco Use with Cigarettes			Polytobacco Use with Hookah			Polytobacco Use with Cigar			Polytobacco Use with Smokeless Tobacco		
		aOR	95% CI	p-value	aOR	95% CI	p-value	aOR	95% CI	p-value	aOR	95% CI	p-value
Race	White (ref)	-	-	-	-	-	-	-	-	-	-	-	-
	Black	**0.40**	**0.36-0.44**	**<0.001**	**0.45**	**0.40-0.50**	**<0.001**	**0.45**	**0.41-0.50**	**<0.001**	**0.30**	**0.26-0.34**	**<0.001**
	Hispanic	**0.49**	**0.46-0.52**	**<0.001**	**0.57**	**0.54-0.61**	**<0.001**	**0.38**	**0.36-0.41**	**<0.001**	**0.30**	**0.27-0.33**	**<0.001**
	Asian	**0.78**	**0.74-0.82**	**<0.001**	**0.88**	**0.83-0.94**	**<0.001**	0.69	0.65-0.73	0.004	0.51	0.47-0.55	0.90
	Other	**0.98**	**0.93-1.03**	**<0.001**	**1.09**	**1.03-1.16**	**<0.001**	**0.86**	**0.81-0.91**	**<0.001**	**0.75**	**0.68-0.80**	**<0.001**
Sexual Orientation	Heterosexual (ref)	-	-	-	-	-	-	-	-	-	-	-	-
	Non-Heterosexual	1.09	1.04-1.14	0.007	1.10	1.04-1.16	0.008	**0.79**	**0.74-0.84**	**<0.001**	**0.52**	**0.48-0.57**	**<0.001**
Lives:	On-campus (ref)	-	-	-	-	-	-	-	-	-	-	-	-
	Off-campus	**1.20**	**1.16-1.24**	**<0.001**	**1.16**	**1.12-1.20**	**<0.001**	**1.09**	**1.05-1.13**	**<0.001**	**1.21**	**1.17-1.27**	**<0.001**
Year in School	1st (ref)	-	-	-	-	-	-	-	-	-	-	-	-
	2nd	1.02	0.98-1.07	0.04	1.07	1.02-1.12	0.72	0.99	0.95-1.04	0.06	0.97	0.92-1.03	0.17
	3rd	1.04	0.99-1.10	0.50	1.09	1.03-1.16	0.45	0.99	0.93-1.04	0.01	0.95	0.89-1.02	0.01
	4th	1.05	0.99-1.12	0.85	1.07	0.99-1.15	0.70	1.04	0.97-1.12	0.44	0.99	0.91-1.07	0.61
	5th	**1.17**	**1.07-1.28**	**<0.001**	1.17	1.04-1.30	0.03	1.12	1.01-1.24	0.01	1.09	0.97-1.13	0.02
Participates in a Greek organization:	Yes	**2.28**	**2.20-2.36**	**<0.001**	**2.26**	**2.17-2.35**	**<0.001**	**2.33**	**2.24-2.42**	**<0.001**	**2.61**	**2.50-2.73**	**<0.001**
	No (ref)	-	-	-	-	-	-	-	-	-	-	-	-
Approx. GPA	A (ref)	-	-	-	-	-	-	-	-	-	-	-	-
	B	**1.69**	**1.64-1.75**	**<0.001**	**1.60**	**1.53-1.66**	**<0.001**	**1.64**	**1.58-1.71**	**<0.001**	1.96	1.87-2.06	0.09
	C	**2.27**	**2.17-2.37**	**<0.001**	**2.01**	**1.91-2.11**	**<0.001**	**2.18**	**2.08-2.29**	**<0.001**	**2.69**	**2.54-2.85**	**<0.001**
	D/F	**3.20**	**2.83-3.61**	**<0.001**	**2.51**	**2.17-2.89**	**<0.001**	**2.73**	**2.38-3.12**	**<0.001**	**3.29**	**2.81-3.86**	**<0.001**
Region	Northeast (ref)	-	-	-	-	-	-	-	-	-	-	-	-
	Midwest	1.07	1.03-1.12	0.04	1.06	1.01-1.12	0.79	**1.23**	**1.17-1.29**	**<0.001**	**1.43**	**1.36-1.51**	**<0.001**
	South	**1.16**	**1.12-1.21**	**<0.001**	1.04	1.00-1.09	0.07	**1.22**	**1.17-1.27**	**<0.001**	**1.37**	**1.30-1.44**	**<0.001**
	West	**0.95**	**0.91-0.99**	**<0.001**	**1.17**	**1.12-1.22**	**<0.001**	1.07	1.02-1.12	0.01	**1.12**	**1.06-1.18**	**<0.001**
Inst. Type	Public (ref)	-	-	-	-	-	-	-	-	-	-	-	-
	Private	**0.90**	**0.87-0.93**	**<0.001**	**0.89**	**0.86-0.93**	**<0.001**	**0.86**	**0.83-0.89**	**<0.001**	**0.72**	**0.69-0.75**	**<0.001**
Campus Size	Small <5k (ref)	-	-	-	-	-	-	-	-	-	-	-	-
	Medium 5-20k	0.99	0.95-1.04	0.15	1.13	1.08-1.20	0.51	1.05	1.00-1.11	0.007	1.02	0.96-1.08	0.70
	Large >20k	1.04	1.01-1.08	0.002	**1.25**	**1.20-1.30**	**<0.001**	1.00	0.96-1.04	0.07	1.02	0.98-1.07	0.52
Current Alcohol use		**12.20**	**11.46-12.98**	**<0.001**	**11.46**	**10.70-12.28**	**<0.001**	**11.11**	**10.42-11.84**	**<0.001**	**10.85**	**10.01-11.77**	**<0.001**
Current Binge Drinker		**6.90**	**6.65-7.16**	**<0.001**	**6.14**	**5.89-6.39**	**<0.001**	**6.30**	**6.06-6.55**	**<0.001**	**7.85**	**7.45-8.26**	**<0.001**
Current Marijuana User		**7.17**	**6.96-7.39**	**<0.001**	**5.78**	**6.56-7.01**	**<0.001**	**5.43**	**5.26-5.60**	**<0.001**	**4.53**	**4.36-4.70**	**<0.001**
Perceived Peer Tobacco Use	0 (ref)	-	-	-	-	-	-	-	-	-	-	-	-
	1	**1.65**	**1.54-1.77**	**<0.001**	**1.50**	**1.38-1.63**	**<0.001**	**1.45**	**1.34-1.58**	**<0.001**	**1.32**	**1.19-1.46**	**<0.001**
	2	**2.21**	**2.07-2.35**	**<0.001**	**2.10**	**1.94-2.26**	**<0.001**	**1.83**	**1.70-1.97**	**<0.001**	**1.77**	**1.62-1.93**	**<0.001**
	3	**2.66**	**2.51-2.83**	**<0.001**	**2.72**	**2.54-2.92**	**<0.001**	**2.75**	**2.58-2.94**	**<0.001**	**2.16**	**1.99-2.34**	**<0.001**
	4	**2.47**	**2.35-2.61**	**<0.001**	**2.77**	**2.61-2.95**	**<0.001**	**2.89**	**2.73-3.06**	**<0.001**	**3.01**	**2.81-3.23**	**<0.001**
	5	**2.80**	**2.40-3.27**	**<0.001**	**1.94**	**1.60-2.36**	**<0.001**	**2.83**	**2.39-3.35**	**<0.001**	**2.15**	**1.75-2.63**	**<0.001**

Notes:

a. Adjusted for study year, institution ID, and age
b. Multiple comparisons corrections: 13 variables, 4 polytobacco use groups, at 0.05. Resulting significance level=0.001
c. Items in bold are significant
d. Sample sizes are the entire analytical male sample

Chapter 3: Patterns of Tobacco, Alcohol, and Marijuana use in College Students

ABSTRACT

Background: Little is known about patterns of multiple product use of these tobacco, alcohol and marijuana (polysubstance use) among college students, particularly for males and females. From a clinical perspective, individuals with differing combinations of use may have different factors associated with use and require different treatment services or prevention approaches.

Objective: Examine the use patterns of tobacco, alcohol, and marijuana use utilizing a latent class analysis and how patterns differ for male and female college students.

Methods: Data were obtained from the National College Health Assessment II Fall 2015 survey on cigarette, cigars, hookah, e-cigarettes, alcohol, binge drinking, and marijuana use. Three separate latent class analyses were completed examining the full sample and males and females separately. Based on the classes determined in the latent class analysis, multinomial logistic regression was performed.

Results: The number of classes, class make-ups, and overall proportions in each class varied by each sample. The entire sample produced a seven-class solution, whereas the male and female samples produced six-class solutions. The resulting classes of male substance use indicated they were more likely to be tobacco, alcohol, and marijuana users who took part in heavier use for all substances. The female classes were more dependent on alcohol to produce class solutions. Overall, in both male and female samples, approximately 40% were a part of a "Global Abstainer" group who did not use alcohol, tobacco, or marijuana. The difference in the number of classes between the entire sample and by gender indicated that specific classes for each gender made up the solution for the entire sample.

Conclusions: Studies utilizing latent class analysis of tobacco, alcohol, and marijuana in the future should run separate analyses by gender. While the resulting number of classes were the same for males and females, the entire sample produced an additional class that was the combination of the male and female solutions. Additionally, the differences in proportions of each sample in respective classes indicates that males and females have specific combinations of substance use that could require additional education and strategies of treatment or intervention.

INTRODUCTION

Background

Tobacco, alcohol and marijuana are commonly used in college populations and contribute to morbidity and mortality in youth and young adults [11,81,90,91]. Interventions addressing substance use in the college setting often address these substances individually [92,93], potentially missing out on an opportunity to address other substances a student may be using or provide individualized treatment. Among college populations, multiple product or polysubstance use (concurrent or simultaneous use within a time period) is common. The prevalence of polysubstance use in college populations has remained consistent over the last decade, whereas rates of cigarette smoking have decreased and the use of marijuana and alternative tobacco products such as such as hookah, cigars and e-cigarettes has increased [11,94].

Polysubstance use of tobacco, alcohol, and marijuana puts individuals at higher risk for negative health and academic outcomes such as mental health issues and greater likelihood of dropping out [95-97]. The combination and frequency of behaviors can be different for each individual [98,99]. Traditionally, polysubstance use in college populations has consisted of cigarette, alcohol, and marijuana use [11], however, hookah, cigars, and e-cigarettes have become popular in college populations, creating a new dynamic of substance use [31,100,101]. The new dynamic coupled with a lack of current knowledge about polysubstance use presents a challenge to both research and to public health practice. Individually, common polysubstance use behaviors are known to be associated with each other and can be predictors of other substance use [18,102], but individuals perceive use of each differently and have different knowledge, attitudes, and beliefs about each [13]. Currently, research examining polysubstance use, including the combinations of substances used, and how polysubstance use behaviors differs by subgroup is highly limited. While

interventions in college populations address polysubstance use [92,103], there is still a lack of needed detail about the polysubstance users' patterns and how differences manifest in male and female populations.

Substance and Polysubstance Use in College Students

Many cross-sectional studies examining tobacco, alcohol, or marijuana assess current use as use in the last 30 days (≥1 day) [43,44,104]. Among college students, 11.6% are current cigarette smokers, 63.2% current alcohol users, 31.9% report having 5 or more drinks in a row within the last 3 weeks, and 21.1% are current marijuana users [11]. While use of cigarettes and alcohol has declined over the last few decades, marijuana use has seen a resurgence among college populations, in addition to new, alternative tobacco behaviors [11]. Among college populations, it is estimated that 14% are hookah users [4,105], 10-12% are users of any type of cigar [106,107], and 9-14% are e-cigarette users [11,56]. While rates of current use of these products has been increasing, of particular concern is the high overall rates of ever use or concurrent use of these products [29,74].

In addition to concurrent use, patterns of past month substance use have shifted toward nondaily use in college populations [108-110]. For instance, while cigarette smoking has traditionally been the main source of tobacco use in college students, daily use of tobacco has dramatically decreased [11]. The decrease in daily cigarette use has been offset by an increase of nondaily tobacco use influenced by the introduction of alternative products, such as hookah, cigars, and e-cigarettes. Additionally, other influences such as increasing social use and continually changing perceptions, attitudes, and knowledge have contributed to a shifting in frequency of use [30,108,111]. Nondaily tobacco use in college students, in addition to alcohol use, has been shown to be strongly associated with social use occurring a few times a month [30,108]. While the overall exposure for nondaily substance users is lower than daily users, nondaily users

still experience negative health and behavioral consequences [109,110,112] and nondaily use can lead to daily use [15,113,114]. Among college cigarette smokers, approximately 70% are nondaily smokers, however nondaily smokers still use other substances such as marijuana and alcohol and as likely to take part in high-risk binge drinking [30,71].

Gender Differences in Substance and Polysubstance Use in College Students

Males and females have been shown to take part in single substance use behaviors at different rates and they each have different predictors of use [11]. College males use tobacco, marijuana, and alcohol at higher rates than females and are more likely to be daily and current (past 30 day) cigarette smokers (daily: 6% vs. 3%; current 16% vs. 9%), report binge drinking (more than 5 drinks for males, 4 for females) and extreme levels of binge drinking (more than 10 drinks) (binge: 37% vs 29%; extreme binge: 22% vs. 7%), and use marijuana annually or daily (annual: 26% vs 19%; daily: 7% vs 3%) [11]. Males also have higher rates of current and ever hookah use [46], cigar use [55], and e-cigarette use compared to females [115].

Aspects of polysubstance use in relation to gender, such as trends or the relationship between two or more substances (alcohol and cigarettes [54], alcohol and marijuana [43,116], cigarettes and other tobacco products [64], or tobacco and marijuana [97,116]) have been examined extensively. These studies however often do not go beyond the associations between use of substances and rarely examine this relationship separately for males and females. The lack of information is a problem particularly for female subpopulations, as they are often used as a reference group due to having lower overall rates of substance use [22,44,79,87]. This limits the ability to detect specific associations with substance use in female subgroups as they may be characteristically different from males. Previous work that has examined polysubstance use

demonstrates that males are more likely to be current users of a combination of tobacco, alcohol, and marijuana and more likely to use a greater number of substances [21,23,26,29,43,53].

Profiles of Polysubstance Use in College Populations

Interventions aimed at college populations addressing multiple substance use lack content or specific components of information on how profiles of polysubstance differ by use frequency and gender [117,118]. Furthermore, as previously mentioned, many studies examining polysubstance use often are association or relationship studies examining two or more substances. While association studies are useful for describing the overall magnitude of the relationship between a two or more behaviors or substances, association studies are a variable-centered [23] rather than a person-centered approach. A variable-centered approach focuses on creating specific groupings of polysubstance use by defining potential combinations. Comparatively, a person-centered approach would take an individual's responses into account and using analysis, define potential combinations. An analysis focused on a person-centered approach, such as a latent class analysis, can provide key information on the intersection of substances used by describing the constellation of substances used. To do this, a latent class analysis (LCA) can examine the underlying, unobservable classes or clusters of substances used by a college student by classifying that individual into common groups based on their use. Furthermore, this method can account for differences in frequency of use and can be stratified to run as separate analyses for sub-groups.

Recent studies have reported examining profiles (groups or classes) of polysubstance or polytobacco use in samples of user and non-user college students or young adults utilizing methods such as latent class analysis or cluster analysis [23,53,98,119]. Each study assessed current use as any use (≥1 day) in the last 30 days and reported both similar and different classes of users

and varying proportions of users. All four studies reported abstainer groups at varying proportions and the structure of classes was heavily dependent on the number of classes selected and if alcohol and binge drinking were in included in the analyses. Only one study however differentiated classes of users by frequency of current use, and none examined differences in class makeup by gender. These studies did assess gender as a covariate, including it in subsequent analyses examining the characteristic make-up of each class. Including gender as a covariate rather than assessing classes separately is problematic as class proportions, the types of substances included in each class, and frequency of substance use are most likely different between genders.

Examining the classes or groups that resulted from these studies provides evidence that specific polysubstance use behaviors are common among users. For example, two studies found polysubstance use groups where users used all substances, whereas the other two studies provided results more evenly distributed between substance types. Primack et al. (2012) conducted a cluster analysis of school year (combined Fall and Spring) NCHA II (National College Health Association II) data using cluster analysis methods [98]. Their study found 6 distinct clusters resulting in groups of abstainers (54%), hookah users (6%), marijuana users who smoke cigarettes and drink (9%), cigarette users who drink (7%), alcohol bingers (17%), and cigar users who use other substances (7%). Haardorfer et. al (2016) used a sample from five college campuses and found 5 distinct clusters including: abstainers (29%), alcohol only (38%), light polytobacco users (16%), heavy polytobacco users (9%), and little cigar/cigarillo, hookah, marijuana users (9%) [23]. Evans-Polce et al. also found 5 distinct groups using a sample from a single university including: non/low users (62%), non-hookah tobacco users (7%), extreme heavy drinkers (12.0%), hookah and marijuana users (14%), and polysubstance users (6%) [53].

Lastly, Erickson et al. used a community-based prospective cohort sample of young adults (including college and non-college) and found 5 distinct groups including: abstainers (60%), cigarette smokers (13%), cigars and hookah users (10%), snus and snuff users (10%), and polysubstance users (7%) [119]. Erickson et. al did not include any form of alcohol use in their analysis, whereas Primack et. al (2012) and Evan-Polce et. al (2016) assessed alcohol use as binge drinking and Haardorfer (2016) assessed alcohol use as current use. From a risk perspective, binge drinking is strongly associated with many health and behavioral consequences among college populations [110,120] including other forms of substance use. Assessing binge drinking without non-binging alcohol users including potentially misses an opportunity to assess the influence of non-binging alcohol use with tobacco and marijuana use. If a respondent was not a binger, they could potentially be misclassified in the wrong group or the models could be underspecified. Additionally, while being male or female was associated with specific classes in each study, it is also plausible that assessment of males and females separately may specify different classes of polysubstance users.

The current study aims to fill the gaps in the previous literature by examining polysubstance user profiles by frequency of use and determine if use profiles differ for males and females. This study will provide greater information as compared to previous work about polysubstance use and gender, as this information currently does not exist.

METHODS

Data source

This study utilizes the most recently available secondary data (Fall 2015) from the National College Health Assessment II (NCHA II) from the American College Health Association (ACHA). The NCHA II is a web- or paper-based ~100-item questionnaire that takes approximately 30 minutes to complete [121]. The survey is available biannually to assess health topics and behaviors in college populations including: alcohol, tobacco, and other drug use, sexual health, exercise and nutrition, mental health, and personal safety/violence. Over 100 universities and colleges participate in the NCHA II survey annually across the United States. The ACHA aggregates surveys from participating schools and offers a national data set available for secondary analysis. For Fall 2015, a total of N= 47 institutions participated with N=19,861 survey respondents. The Virginia Commonwealth University Institutional Review Board deemed the current study exempt as de-identified as secondary data were used.

Measures and Recoding

Tobacco, Alcohol, and Marijuana Use

This study assesses frequency of current (last 30 days) substance use of seven behaviors including: cigarettes, hookah, cigars, e-cigarettes, alcohol, binge drinking, and marijuana. Excluding binge drinking, the substance use behaviors were assessed as: "Within the last 30 days, on how many days did you use (*substance)*:" Responses include: "Never used", "Have used, but not in the last 30 days", "1-2 days", "3-5 days", "6-9 days", "10-19 days", "20-29 days", or "Used daily".

Substance use behaviors (cigarettes, hookah, cigars, e-cigarettes, alcohol, and marijuana) were recoded based on frequency into three-level ordinal variables: No use ("Never used", "Have used, but not in the last 30 days"), occasional use ("1-9 days"), and frequent use (10+ days). To fully examine the distribution of the behaviors, various recoding schemes were assessed, but ultimately not used including: a four-level recode of all past 30-day substance use, a three-level recode, coding 10-19 days with 1-9 days, and daily ("Used daily") versus non-daily use ("1-29 days"). The chosen three-level recode of: No use ("Never used", "Have used, but not in the last 30 days"), occasional use ("1-9 days"), and frequent use (10+ days) was selected based on distribution of use (for most substances, about equal numbers in occasional and frequency use categories) and usefulness of resulting "groups" or "clusters" in the final analysis.

Binge Drinking

Previous work regarding groups or classes of college substance users have either examined only alcohol use or only binge drinking[98,122,123]. However, studies often examine either current alcohol use or binge drinking measures and not both, omitting individuals who are high risk if current use is selected (binge drinkers) or individuals who are still self-reported users if binge drinking is selected (use alcohol, but don't binge drink). Thus, for this study, both alcohol use in the last 30 days and binge drinking in the last two weeks are included. The survey assessed binge drinking as, "Over the last two weeks, how many times have you had five or more drinks of alcohol at a sitting:". Responses include: "N/A, don't drink", "None", "1 time" through "9 times", or "10 or more times". Binge drinking was recoded to an ordinal variable as: No binge drinking, occasional binge drinking (1 or 2 times), or frequent binge drinking (3 or more times).

Demographics, Individual, and School Characteristics

Self-reported demographic, individual, and school characteristics are included as covariates in this study. Demographic and individual characteristics are self-reported, whereas school characteristics are reported by each institution.

Demographic variables assessed in this study include: sex/gender, age, and race/ethnicity. For sex/gender, the secondary dataset is distributed with a recoded variable that takes into account biological sex and a self-identified gender (three-levels: Male, Female, and Non-binary). Second, age is self-reported by respondents as a write-in response based on the following question: “How old are you?”. Lastly, race/ethnicity is assessed as: “How do you usually describe yourself? (Mark all that apply)”. Responses include: “White”, “Black”, “Hispanic or Latino/a”, “Asian or Pacific Islander”, “American Indian, Alaskan Native, or Native Hawaiian”, “Biracial or Multiracial”, or “Other”. To create a race variable for analysis, respondents who marked more than one answer, were recoded as “Biracial or Multiracial”. Upon examining the distribution of the recoded race variable, due to small numbers (less than 3% of all respondents for each category), three groups were collapsed into an “Other” category including: “American Indian, Alaskan Native, or Native Hawaiian”, “Biracial or Multiracial”, and “Other”.

Individual characteristics relating to non-demographic student information are also assessed in the survey including: year in school (1st-5th), participation in a Greek-letter fraternity or sorority (yes/no), approximate self-reported grade point average (A, B, C, D/F, N/A), and campus residence (On-campus/Off-campus). Last, school characteristics related to the institution are assessed as measures of the institutional environment and include: region of campus (Northeast, Midwest, South, or West), population size of locality (small locale: ≥50,000 or large local: <50,000), public or private institution, and size of campus (large >10,000 or small/medium

<10,000). All individual and institutional characteristics have been shown to be associated with college substance use and have previously assessed in similar studies [98]

Study Population and Analytical Sample

Participants included in this sample included undergraduate college students attending a US based institution between the ages of 18-24 and who self-identified in one binary gender category. The final study analytic sample size was N=14,504 with n=9,926 females and n=4,578 males.

Statistical Analyses

Latent Class Analysis

In general, latent class analysis (LCA) or latent modeling is appropriate when there is reason to believe that an underlying or latent structure exists among observable variables. The latent structure or construct is normally unobservable and relies on observable variables to create the structure. The latent construct, often denoted as *C* with a circle, is constructed based off indicators X_1, X_2,… X_j, surrounded by rectangles. For this study, the indicators are represented by the seven substance use behaviors. In the context of this study, while polysubstance use behaviors could be created based on defined combinations of use using the observed single-use behavior responses, the resulting polysubstance use classes would be extremely difficult to determine and the interpretation based off all potential combinations. The data used in this study has several different substance use variables that could be used to display a pattern of use for each individual. There may be practical, real-world examples of such patterns such as, individuals who drink alcohol and smoke cigarettes in bars. However, individuals in one class

cannot be belong another as latent class analysis assumes that the structure is mutually exclusive. Figure 3.1 represents a latent class model.

Latent class analysis was selected as the method of choice for this study as it has the ability to handle categorical variables that can be binary or ordinal in nature. Other types of latent modeling including latent profile analysis (LPA), and growth mixture modeling (GMM) were not suited for the type of data used in this study or type of results needed. LPA is similar to LCA in that a latent, categorical variable is modeled from continuous variables and GMM requires longitudinal, continuous indicators. The data set used for this study is cross-sectional and recoded into three-level ordinal variables.

There are two parameters are of interest in a LCA: the conditional item probabilities and the posterior class membership probabilities. Posterior class membership probabilities are defined as the overall probability for classification of an individual based on their most likely class membership and can be used to estimate the class prevalence proportions.

Since the posterior class membership probabilities rely on a respondent's endorsement of indicators or behaviors, given the respondents response pattern as:

$$u = \left(U_1 = r_1, \ldots, U_j = r_j\right)$$

Where u = class membership, overall response pattern of variables included in analysis

U_1 = likelihood of endorsement of individual behaviors

and denoted as $\gamma_{c|u} = \Pr(C = c|\, U = u)$.

Conditional item probabilities are the probability that an item is endorsed for a latent class. In the context of this study, the class proportions are the overall proportions of individuals

falling within each latent class and the conditional item probabilities are the probability that a substance use behavior is endorsed for a single class. The conditional item probability can be represented as the probability for endorsing r_j for any X_j, conditional on membership in class c, as: $\rho_{j,r=rj|c} = Pr\left(X_j = r_j | C = c\right)$.

Where X_j = a specific substance use variable

r_j = respondent selection coded dichotomously as 0= No use, 1= User

The overall class prevalence is estimated as

$\pi_c = \Pr(C = c)$ for any c class, c=1, …, C.

Therefore, an LCA is the product of the probability of being in a class given the likelihood of responding to using a specific substance and as such, the general formula for a latent class model is $\Pr(U = u) = \sum_{c=1}^{C} \Pr(C = C) \prod_{j=1}^{J} \Pr\left(U_j = r_j \middle| C = c\right)$. Membership in a class is based on the sum of probabilities for the class (must sum to 1; posterior probability) combined with the probability for use of a substance within a single class (conditional item probability).

There are two primary assumptions in LCA: first, that there is local independence between the indicators and second, that individuals are independent. Local independence between indictors means that the correlation between the indicators is explained by the latent class whereas individuals must be independent and that an individual's class membership does not affect another respondent's class membership.

LCA Model Fit and the Process of Model Selection

To determine the optimal number of classes for the three model sets, the guidelines provided by Nylund et al. were used [124]. There is not a currently accepted method for determining the correct number of classes. However, there are statistical indicators that are commonly used to select the best fitting model (the model that best explains the data), specifically model fit and parsimony. Model fit is used to describe each model compared to other models based on a series of fit statistics. Model parsimony is defined as how well an explanatory predictive model explains the data while using the minimum number of parameters. For LCA, comparing model fit between a different iterative number of classes can provide an indication as to the correct number of classes, however, that model, may not be the most parsimonious. In many instances, a model with good fit, will have low parsimony.

An LCA typically requires a systematic approach to identifying the best fitting model (i.e., a model with the appropriate number of classes). A series of several models are estimated where each successive model iteratively increases the number of classes from the previous model. The iterative runs proceed by starting with a one-class model and then increasing the number of classes. After all models have been run, their results are compared to determine the one that is most parsimonious (via measures of model parsimony) and that has the best model fit (through comparison of the log-likelihood).

A challenge in LCA model selection is that models tend to be more parsimonious simply by adding another class as the overall number of parameters increases during model selection. As the number of classes increases, the overall number of parameters increase due to the additional class, the number of variables being assessed, and number of levels of each variable. Nylund et. al suggest that four statistical tests provide the best estimate for determining the number of

classes: Bootstrapped parametric likelihood ratio test (BLRT), Bayesian Information Criterion (BIC), Adjusted Bayesian Information Criterion (Adj. BIC), and Vuong Lo-Mendell-Rubin test (VMLRT) [124]. The Akaike Information Criterion has also been previously used, but tends to be inferior to the BIC or Adj. BIC [124]. The BIC, adjusted BIC, and AIC are used to compare models and weight both model fit and parsimony whereas the BLRT and VMLRT are measures of model fit, but do not take parsimony into account.

In simulation studies, all four tests consistently perform well, however the BLRT, BIC, and Adj. BIC appear to be the most consistent in selecting the correct number of classes [124-126]. The Adj. BIC differs from the BIC in that $Adj.BIC = -2\log L + p\ log(\frac{n+2}{24})$, whereas the BIC is: $BIC = -2\log L + p\ log(n)$. The BIC and Adj. BIC seek to provide an indicator of model selection by weighting both model fit and parsimony. The adjusted BIC simply weights the statistic based on sample size. For either BIC statistic, when comparing different runs of increasing number of classes, the lowest value suggests the “correct” number of classes. Comparatively, the BLRT and VLMRT, which are likelihood ratio tests, provide a statistical value and p-value with each increasing class run and can be used to compare the increase in model fit between *k*-1 and *k* models (*k*=number of classes). When the p-value of these tests is >0.05, this indicates that compared to the *k* number of classes, the *k*-1 model is statistically a better fit. Both are based off the equation for the likelihood ratio: $LR = -2\,[\log L(\hat{\theta}_r) - \log L\,(\hat{\theta}_u)]$, where $\hat{\theta}_r$ is the maximum likelihood (ML) estimator for the more restricted, nested model and $\hat{\theta}_u$ is the ML estimator for the model with fewer restrictions. As an example of how to interpret a likelihood ratio test for LCA, the process begins with a 1 class solution and iteratively increases the number of classes (K). At each step, the p-value for each test (BLRT and VMLRT) is examined. Once the p-value for each test increases above 0.05, that test indicates that a K-1

model is the better fit and the iterations are stopped. As an example, if iterations are done increasing class solutions starting at one class and increasing to five classes where the p-values both the VMLRT and BLRT are observed as being greater than 0.05, these tests indicate a significant different in a 5-class model fit and suggest that 4 classes is a better solution. In addition to the fit statistics, an entropy value is provided with each model run as a measure of classification fit. An entropy value of > 0.70 indicates good classification fit, but the higher the value, the better the classification. Entropy values, however, cannot be compared between increasing number of classes and should not be used as a fit statistic.

Latent Class Analysis of Polysubstance Use

The primary aim of this study is the assess gender differences in polysubstance use groups by frequency of use using a nationally representative data set on college students (NCHA II). To accomplish this aim, three latent class analyses (LCA) were completed examining the full sample, a male-only sample, and a female-only sample. The resulting classes describe groups of polysubstance users by frequency of each substance used. Additionally, based on the increasing rates of nondaily use of tobacco products, rather than simply examining any current use in the last 30 days [23,53,98], this study examined the influence of frequency of use within the latent classes in order to further provide descriptive information on profiles of polysubstance use.

Advantages of Latent Class Analysis

The NCHA II Fall 2015 dataset is an appropriately suited sample for a latent class analysis approach due to its large sample size and availability to recode variables into collapsed, ordinal levels. In general, LCA is dependent on the overall sample being analyzed. The dependence on sample size becomes particularly critical when examining a large number of

variables, a large number of classes, or variables that are ordinal in nature with more than 2 levels [124], all of which are true for this study. Additionally, unlike other methods such as regression, where multicollinearity is an issue, LCA is designed for variables that are correlated. The strong relationships between tobacco, alcohol, and marijuana use often mean that these behaviors are highly correlated, which can be a problem for association studies as use of one substance can linearly predict use of another substance, violating assumptions of independence between variables. Prior to conducting descriptive and latent class analyses, correlation coefficients between each behavior in this study were examined. Values ranged from 0.39-0.75 for the full sample, with cigarette smoking and all behaviors and alcohol use and binge drinking having the strongest correlations.

Two statistical packages were used for analyses. SAS version 9.4 was utilized for data management, recoding, and subsequent analyses completed after LCAs were finalized. Mplus version 7 Base Program and Mixture Add-on was utilized to conduct all LCA modeling. The process of model selection used in this study, including use of the statistical indicators and the resulting classes is reported in the *Results* section. Model code for one class iteration of the Full sample can be found in Appendix A.

Descriptive and Multivariate Analyses of Latent Classes of Polysubstance Use

In the final step of a LCA, respondents were assigned to a class. Descriptive analysis was conducted examining student and institutional characteristics. Chi-square tests were performed to test for significant differences between males and females. Multinomial logistic regression was conducted for each model set (full sample, males only, and females only) to obtain adjusted odds ratios and 95% confidence intervals examining associations between class membership and students and institutional characteristics. For these models, the assigned group was the dependent

variable (outcome) and independent variables were covariates relating to individual and institutional characteristics. The regression analysis for the full sample was adjusted for gender and school identification number to address any clustering by respondents attending the same institution. For the Male and Female only models, only the school identification number was controlled for. Multiple testing corrections were applied in this study using a Bonferroni correction. The resulting significance level was p=0.001.

Justification of Analyses

For this study, it was initially proposed that three stratified cluster analyses would be conducted (full sample, males only, and females only) to compare how the frequency of substance use behaviors differs between genders. Previous research has examined NCHA II data from 2009 using cluster analysis, where the behaviors were dichotomously coded as either “use in the last 30 days” or “no use in the last 30 days” [98]. In this study, three levels of use including “no use”, “occasional use”, or “frequent use” were coded for and three cluster analyses were performed using the Two-Step Algorithm in SPSS [127].

Cluster analysis has commonly been used for behavioral research and has the ability to detect “natural groupings” of data. Data observation measurements that tend be similar, as measured by shorter distance, are considered clustered, whereas other objects that are dissimilar are in another cluster or further away. The Two-Step Algorithm seeks to address common issues with two types of cluster analysis methods: K-means clustering and Hierarchical Agglomerative Clustering. In K-means clustering, the number of clusters is inputted by the user and run with different numbers of K clusters in order to receive an “optimized” result. The k-means algorithm, by its own nature, is unable to determine the number of clusters and have to be specified by the user. Hierarchical Agglomerative Clustering is a bottom-up approach to the data that uses

minimized distances between clusters that are iteratively merged until a single cluster exists. Each step or agglomeration produces a greater distance between the clusters than the previous step. A resulting dendrogram at each iteration can be used as a visual representation of how the data is segmented. Similar to the K-means clustering, hierarchical agglomerative clustering also cannot determine an optimal number of clusters. The Two-Step algorithm seeks to address these shortcomings by producing pre-clusters in the first step and then sequentially measuring and merging clusters based on a log-likelihood distance measure. The optimal number of clusters are outputted and determined based on a Bayesian Criterion (BIC) and Ratio of Distance Measures.

For this study, the three cluster analyses completed using the Two-step algorithm consistently displayed that a two or three cluster solution was optimal for the data. This presented issues as previous research has shown that among substance and tobacco users, there are distinct groups of users [23,53,98,119]. Due to the Two-cluster algorithm only presenting a few groupings, it was believed that this method was having issues due to each substance use variable having three frequency levels. Thus, three latent class analyses were performed on this data to determine the optimal number of latent classes of substance users by frequency levels and gender. LCA methods have been noted to have advantages over other grouping methods including: management of mixed measurement types (particularly ordinal for the data used in this study), better handling of missing data, classification probabilities for individual classification, and greater classification accuracy [127-129].

RESULTS

Demographic and Institutional Descriptives

Full Sample

Respondent demographic and institutional characteristics are shown in Table 3.1 (N=14,504). The average age of respondents was 19.8 years, over 70% of the sample was White, 32% where in their first year of school, 51% lived on campus, 14% participated in a Greek-letter fraternity or sorority, and on average, nearly all were A or B students (89%). Over 38% attended an institution in the South, 70% attended a public institution, over 72% attended an institution with a student population larger than 5,000 students, and 82% attended in an institution in a locale with a resident population larger than 50,000.

Males and Females

There was a total of 9,926 females (68%) and 4,578 males (32%) in the study sample (Table 3.2). The average age of males (20.0; SD=1.61) was higher than females (19.7; SD=1.50) and the samples were proportionately equal by racial groups, students' year in school, and living on campus. More female respondents (14%) participated in Greek-letter organizations than males (13%). Males generally had a lower grade point average. For students' institution, there were equal proportions of region of institution and attending a public institution between genders. A larger proportion of male respondents (79%) attend an institution with a population larger than 5,000 than females (70%) and more males (85%) attended an institution with a resident population greater than 50,000 than females (82%).

Tobacco, Alcohol, and Marijuana Use Descriptives

Full Sample

The highest proportion of tobacco users were occasional users using between 1 and 9 days out of the last 30 for all tobacco products (Table 3.2). Among cigarette smokers, 5.7% were occasional users (1-9 days) and 2.9% (10 or more days) were frequent users in the last 30 days. For hookah, 4.8% were occasional and 0.7% were frequent users. For cigars, 4.3% were occasional users and 0.5% frequent users. For electronic cigarettes, 3.6% were occasional users and 1.6% were frequent users. More than half of the respondents reported using alcohol in the last 30 days with 44.6% reporting occasional use and 12.4% frequent use. However, only 13.0% reported binging alcohol occasionally (1 or 2 times), while 18.5% reported frequent alcohol binging (3 or more times) in the last 30 days. For marijuana, 10.8% reported occasional use and 5.7% reported frequent use.

A larger proportion of respondents used at least one substance, however 39.4% reported not using a substance (Table 3.4). Of the full sample, 22.7% used one substance, 20.4% used two substances, and 17.6% used more than three substances. For tobacco use, 14% used at least one tobacco product (cigarettes, hookah, cigars, or e-cigarettes), 5.7% were dual-tobacco users, and 1.7% were polytobacco users. Various combinations of tobacco use and other substance use can be found in Table 4.

Males and Females

Among all substance use behaviors, males had higher rates of frequent use (10 or more days) than females (Table 3.2) (cigarettes: 4.1% vs. 2.4%; hookah 0.8% vs 0.6%; cigars 0.8% vs. 0.3%; electronic cigarettes: 3.2% vs. 0.9%). For occasional use, however, males had higher rates

of use for all tobacco products, marijuana use, and binge drinking, whereas females had a higher frequency of occasional alcohol use (46.1% vs. 41.2%)

Nearly equal proportions of males and females were either abstainers (39-40% reporting using 0 substances) or used two products (~20%; Table 3.4). There were differences between genders for all other substance use. Females self-reported more often using a single substance (males: 21.3%; females: 10.6%), however, more than twice as many males self-reported using four or more substances than females (males: 12.9%; females: 5.7%). The difference in the number of substances used was more pronounced when examining multiple tobacco use; 9.5% of males were dual-tobacco (two tobacco products) users compared to 3.9% of females, while 3.1% of males reported polytobacco (>3 substances) use compared to 1.0% of females. The differences in prevalence rates among multi-product tobacco users, were similar for other polysubstance use as more males often self-reported alcohol use with binge drinking (males: 36.7%; females: 27.1%) whereas more females more often self-reported alcohol use and no binge drinking (males: 19.2%; females: 30.2%).

Latent Class Analysis Results

Model Selection

In addition to the statistical indicators, all model runs and class solutions were examined for face validity (i.e. does the number of classes, combinations of classes, and resulting class proportions and probabilities make sense). All model sets started with a 2-class solution and ended with a 10-class solution (Table 3.3). The 10-class solution was selected as a finishing point during the iterative runs as class proportions for the 9- and 10- class solutions had percentages below 1.0% for membership of two classes (two few individuals in these classes). In

all model sets, the BIC (and adjusted BIC) remained stable from start to finish whereas the BLRT and VMLRT gave inconsistent results. For the likelihood ratio tests, to obtain a model that fully converged it was required that the STARTS and LRTSTARTS options be used. The STARTS and LRTSTARTS values used to obtain a run that converged for both options were extremely high and required significant computation time, suggesting that the BLRT and VMLRT are not as trustworthy with the selected models.

Prior to conducting the LCAs, it was determined that 39.4% of the full sample, 39.5% of males, and 39.0% of females did not use any of the substances in the last 30 days. Therefore, it was expected that a class would emerge in all model runs with a proportion near the respective "abstainer" percentages. Results from the LCAs provide class proportions which can then be compared to the actual sample. The class proportions are based on a probability that an individual is similar to others in their class. In conjunction with a fit statistic, a class proportion "close" to the expected proportion could indicate the correct number of classes. The class proportion would most likely be higher as all of the "expected" respondents would Fall into that group and based on the probabilities, may capture others. Thus, based on the guidelines by Nylund et. al, the overall classes proportions, and the substance use probabilities within classes, the adjusted BIC was selected as the indicator for determining the correct number of classes [124].

The four tests (BIC, adjusted BIC, VMLRT, and BLRT) from the LCAs for all the models were highly discrepant within each set. It is expected that the VMLRT and BLRT provide similar class solutions, however as demonstrated in Table 1, the VMLRT and BLRT were far apart in their class solutions and for the full sample model run, the BLRT never specified. Due to this inconsistency, the additional required examination of class proportions for solutions selected by the BLRT and VMLRT, and the extensive programming requirements for

the BLRT and VMLRT to properly converge, class solutions based on the BLRT and VMLRT were not selected for any of the model sets. After determining the BLRT and VMLRT were not viable for the model solutions, the BIC, Adjusted BIC, and respective proportions for class solutions were compared. The BIC consistently underspecified the models (few overall number of classes) and in all three model sets, the abstainer group was a significantly higher proportion than what was expected indicating that the BIC most likely did not produce the “correct” class solutions. The adjusted BIC however, produced an expected number of classes and class proportions and was consist across the model sets.

Based on the Adj. BIC, the full sample model set indicated a 7-class solution, the Female model set a 6-class solution, and the Male model set a 6-class solution. Class proportions were further examined for these models and classes in addition to estimates of probability scales. The estimates of probability scales are proportions of individuals that likely make up each frequency level of each behavior within each class. For each latent class of a selected model, the estimates of probability scale break down the proportion of individuals who did not use, occasionally used, or frequently used for each of the substance use behaviors. To be considered as a “primary” behavior within classes, probabilities of frequency of substance use needed to add up to greater than 50% for any behavior (i.e. occasional and frequent use be greater than 50% for that behavior to be important to a specific class).

Latent Classes: Full Sample

The largest class produced (43.8%) was a “Global Abstainer” class who did not take part in any substance use (Figure 3.2 and Table 3.5). The second largest class, “Non-bingers” (37.2%), was a class of alcohol users who only use occasionally and never binge drink. Additionally, this class did not use any tobacco products or marijuana. The third largest class,

“Binge Alcohol and Use Marijuana”, (7.3%) consisted of occasional alcohol users who binge drink and use marijuana both occasionally and frequently. The fourth largest class, “Alcohol Bingers”, (5.9%) consisted of occasional alcohol users who binge frequently (3 or more times in last 2 weeks). Among the smallest three classes were users of tobacco products. The fifth largest class, “Binge Alcohol, Use Cigarettes & Marijuana” (3.5%), were occasional cigarette smokers who use marijuana occasionally or frequently, frequently use alcohol, and frequently binge drink. The sixth largest class, “Cigarettes Only” (1.4%), consisted of cigarette only smokers who were split between using on occasion or frequently. The last class, “Polysubstance users”, made up only 1.0% of the sample, but were users who take part in every behavior. This group used all tobacco products occasionally but also were frequent binge drinkers and marijuana users.

Latent Classes: Males and Females

Together, the overall class proportions and probabilities for each substance use were different, however there were some similarities in the types of classes (females: Figure 3.3 and Table 3.6; males: Figure 3.4; Table 3.7). For both genders, the largest overall class was a “Global Abstainer” class who made up 44.3% of females and 42.2% of males. The second largest class for females “Non-bingers” (41.2%), occasionally used alcohol. For males, a “Non-bingers” class did not exist, but instead an “Alcohol Bingers” class was produced as the second largest class (38.0%), who occasionally used alcohol, but binged occasionally and frequently. The “Alcohol Bingers” class existed for females, but only made up 7.0% of the sample (third largest). The third largest class for males was a group who “Binge Alcohol, Use Cigarettes & Marijuana” (8.5%). This group occasionally or frequently cigarette smokers and marijuana, but frequently used and binged alcohol. A similar class was found among females, “Binge Alcohol, Use Cigarettes & Marijuana” (fourth largest), but the proportion of females in this class was lower (2.9%) than the

male class. The fourth largest class for males, "Binge Alcohol and Use Marijuana" both occasionally and frequently use marijuana, but also occasionally use alcohol, but frequently binge. A similar class was produced for females, ("Binge Alcohol and Use Marijuana"), but only made up 2.9% of the female sample. The fifth largest class for males, "Cigarettes Only", was a class of occasional or frequent cigarette smokers who did not use any other tobacco product or substance. This class was absent from the female solution. The smallest class for females, "Cigarettes & Alcohol" (1.9%) occasionally or frequently smoke cigarettes, but also occasionally used alcohol (no binge drinking). The final class for males, "Polysubstance users", only made up 1.3% of the male sample, but they were users who take part in every substance use behavior including occasional or frequent tobacco and marijuana use and frequent alcohol use and binging. A class of "Polysubstance users" did not exist for females.

The 6-classes between the male and female model sets combined produced the 7-class solution from the full sample (i.e. all classes in the males and female samples were represented in the full sample), however proportions between each model set differed. The primary differences observed between the male and female models sets included: a "Polysubstance use" class for males, but not for females, an "Alcohol Non-binger" group for females, but not for males, and vastly different proportions of class size and probabilities of frequency of use of substances within classes by gender. As an example, the "Alcohol Bingers" class for females only consisted of 7% of females, whereas the overall proportion for males was over 38%. Among these same classes, the probability distribution in the male "Alcohol Bingers" class leaned toward frequent use and binge drinking, but for females, occasional use and binge drinking.

Multinomial Regression

Full Sample

All multinomial regressions were conducted using the "Global abstainer" class as the reference group (Table 3.8). Most polysubstance use classes were strongly, positively, and significantly associated with participating in Greek-letter organizations, living off campus, and having a grade point average below an A. For the male "Polysubstance users" class, there were moderate, positive, and significant associations with a grade point average below an A and participating in Greek-letter organizations. Additionally, being a race other than white, being in a year in school past the first year, and living in a region other than the west was moderately and significantly associated for "Binge Alcohol, Use Cigarettes & Marijuana", "Alcohol Bingers", "Binge Alcohol and Use Marijuana", and "Non-bingers" classes.

Females

All multinomial regressions were conducted using the "Global abstainer" class as the reference group (Table 3.9). For females, most class solutions were strongly, positively, and significantly associated with participating in Greek-letter organizations, living off campus, and having a GPA below an A. The associations with specific racial groups and year in school with class solutions was not as widespread as demonstrated with the full sample, however being beyond the first year in school was associated with being in "Binge Alcohol and Use Marijuana", "Binge Alcohol, Use Cigarettes & Marijuana" "Alcohol Bingers", and "Non-bingers".

Males

All multinomial regressions were conducted using the "Global abstainer" class as the reference group (Table 3.10). For males, most class solutions were strongly, positively, and

significantly associated with participating in Greek-letter organizations, having a GPA of B or C, and attending a school in the South or Midwest. Similar to females, significant associations were not as widespread as demonstrated in the full sample, however "Binge Alcohol, Use Cigarettes & Marijuana", "Binge Alcohol and Use Marijuana", and "Cigarettes only" classes were moderately and significantly associated with each one year increase in age, living off campus, and protective for some racial groups.

DISCUSSION

The primary purpose of this study was to examine polysubstance user profiles by frequency of use and by gender. Seven distinct classes of were found when examining the full sample, whereas six classes were specified for males and six classes for females. Within each sample (entire, male, and female), four classes were identical based on the combination of substances used including: "Global Abstainers", "Alcohol Bingers", "Alcohol Bingers and Use Marijuana", and "Binge Alcohol, Use Cigarettes and Marijuana". However, the overall class proportions and the probabilities of substance use by frequency in these classes were different between the samples.

Besides "Global Abstainers", which made up 43% of each sample, the remaining three equivalent classes between the samples made up between 3-9% of each sample. Interestingly, for the full sample and for females, the second largest class consisted of non-bingers, whereas for males, the second largest class was an "Alcohol Bingers" group. The three remaining classes in the full sample were "Polysubstance users", "Cigarettes Only", and "Non-bingers". The "Polysubstance users" were present in the male only sample, the "Non-bingers" in the female only sample. The "Cigarettes Only" class was present in the male sample, however this group for females was specified as a "Cigarettes and Alcohol" class. Overall, alcohol was used in nearly all

classes except for the abstainer groups and those in the entire and male samples who only used cigarettes.

Examining the probabilities of substance use in each class was highly informative from an interpretation standpoint. In all classes (except global abstainers), males were nearly always frequent substance users whereas females were occasional users. Without examining males and females separately, the difference in use frequency would have been missed in the full sample where the probabilities tended to attenuate away from frequent use and distribute evenly between the levels of use (occasional and frequent). Additionally, in the full sample and the male only sample, users of alternative tobacco products (hookah, cigars, and e-cigarettes) were a part of the Polysubstance use group. In the female sample, the alternative tobacco behaviors were not specified into any of the classes. Nonetheless, while there are male and female users of alternative products, the overall proportion of users who use any of these products was relatively small (approximately 5% for each behavior) and splitting the behaviors by frequency of use may have limited the sensitively of the latent class analyses to place these individuals into separate groups. Examination of the probabilities of substance use by frequency demonstrates that within the classes that had any sort of polysubstance use, there are individuals who take part in these behaviors, but the probabilities were below 50% and thus, these behaviors were not included as primary behaviors for that class.

The more frequent use patterns observed in males were evident even without examining the classes. Males had significantly higher rates of frequent (≥10 days of last 30) and occasional (1-9 days) of tobacco use (cigarettes, cigars, hookah, or e-cigarette), binge drinking (occasional: 1 or 2 times last 2 weeks; frequent ≥ 3 times last 2 weeks), marijuana use, and frequent alcohol use whereas females had higher rates of occasional alcohol use. Males took part in significantly

more behaviors in than females and were more likely to be dual or polysubstance users. Additionally, males had significantly higher rates single-, dual- or polytobacco use and tobacco use in combination with marijuana, alcohol, or binge drinking. Lastly, males had higher rates of alcohol and binge drinking, whereas females had higher rates of alcohol use without binge drinking.

A total of seven distinct classes were found in the full sample and four of the seven classes could be considered to be polysubstance use (multiple: i.e. 2 or more) classes including "Polysubstance users", "Alcohol Bingers", "Alcohol Bingers and Use Marijuana", and "Binge Alcohol, Use Cigarettes and Marijuana". These same polysubstance classes were found in males, however instead of "Polysubstance users" in females, they were "Cigarettes and Alcohol". Polysubstance classes made up 22% of the full sample, 15% of the female sample, and 56% of the male sample.

A range of demographic, individual-level, and institutional levels variables were associated with being in a polysubstance class (multiple behaviors) compared to being a Global Abstainer class in all of the samples, particularly for males. The classes of polysubstance use participated in Greek-letter organizations, had lower grades, use alcohol, binge drank, use marijuana, and attended a school in the Midwest. In general, living on campus and being a race other than white, was a protective factor for being in a polysubstance use class. These specific associations carried across both male and female samples. In particular, participating in a Greek organization and low GPA have been shown to be strongly associated with substance and polysubstance use in college populations [58,76,130]. Interestingly however, the associations seen for participating in a Greek organization were much stronger in males and females, suggesting that males in Greek organizations are at a higher risk for polysubstance use. These results were

similar to other studies, which also observed that individuals in Greek-letter organizations and were male, were significantly more likely to be in a polysubstance use group [23]. The major difference between this study and those that have examined classes of polyuse in college students are the differences noted between classes of use in males and females. The difference use patterns and the specific associations with polyuse for males and females suggest that different targeting approaches need to be taken to address different types of use in each gender. This result extend the results of previous studies which all found different combinations but similar associations to this study [23,53,98].

Specific classes of polysubstance use and region of institution can be explained by regional cultures associated with tobacco, alcohol, and marijuana use. This not only includes the popularity or social acceptability of specific products, but also includes policy-related effects such as drinking and smoking age and legalization of marijuana. Many campuses have made an effort to address or restrict tobacco, alcohol, and marijuana use through policies, initiatives, and campaigns against use [131,132]. This includes banning substance use on campus, having events where substance use is not allowed, and mandating students live on campus. The associations observed between polysubstance use and living off campus are plausible as those in residences not under the jurisdiction of campuses may have more exposure and opportunities to use tobacco, alcohol, and marijuana. Differences in other health outcomes, such as obesity, have been seen in students living on or off campus [133].

Study Limitations

This study has several important limitations. First, there were differences in the overall sample sizes and possible response rates between males and females. Individuals may self-select depending on how participating universities invite survey participants. Any bias related to self-

selection however may be overcome by the large overall sample and that the overall proportions of males and females in this study are similar to the current national rates [88]. Second, there is currently no universally accepted method for determining and selecting the correct number of classes in latent class analyses. To overcome the lack of a standard method, this study used both suggested methods from previous research [124] and interpretability of class proportions and probabilities of substance use for each sample. Third, the study sample is from the NCHA II and is considered a nationally representative sample. However, as with any survey examining substance use, this study may be subject to selection and social desirability biases. This study is also limited by the self-response nature of the survey as substance use is often underreported [134]. Fourth, the cross-sectional design limits the causality and temporality of the subsequent analysis and the relationships between covariates and class memberships. To fully understand profiles of substance use from a risk perspective and apply results to individualized interventions, future studies could utilize multi-wave or longitudinal data and apply latent transition analysis. The NCHA II survey however is cross-sectional and students are not followed. Utilizing a method of longitudinal surveying would allow for determining changes in profiles of substance and polysubstance use overtime to identify the individuals who are at highest risk. Fifth, this study defined binge drinking as 5 or more drinks at a sitting for males and females. Other research has determined that 4 drinks may qualify as binge drinking for females [109], which could mean that females in this study were under-classified as non-binge drinkers, when they actually are binge drinkers. Additionally, the measure of binge drinking may not be the correct measure for determining alcohol-related “risk” as new measures including a calculated estimated BAC can now be utilized in the NCHA II. Using this measure in conjunction with past 30-day alcohol use could provide a new, standardized measure for risky alcohol behaviors in college males and

females. Lastly, future work needs to focus only on users as inclusion of non-users could actually change the overall class solutions and proportions due to the amount of variance in the model because of a large “non-user” group.

Implications and Conclusions

The findings from this study have important research and practical implications. This study found that future latent class analyses need to examine substance use behaviors for males and females separately and need to take frequency of use into account within these analyses as differing profiles of use exist between genders. Furthermore, due to the influence of alcohol on the latent class analysis solutions, studies examining multi-product tobacco use should not include alcohol in LCA model building. Additionally, determining individuals who were non-users and excluding them from the analysis may prove beneficial to the overall model building process. Nonetheless, the confirmation that differing profiles of use exist by gender suggests that the use of latent class analyses can inform interventions targeting specific individuals or subgroups. Future studies examining profiles polysubstance users could take a different approach to classifying individuals and only include respondents who are considered users. This study and previous research have demonstrated that a group or class of non-users exists [23,98]. With a large enough sample, the inclusion of only users could provide more specified models by limiting the amount of variance in the model related to nonusers.

From the perspective of campus-based services providing cessation or interventions, the large percentage of each sample that were “Global Abstainers” is a promising result. These individuals do not take part in any substance use and should be more closely studied to determine if there are specific characteristics or factors that contribute or are associated with their non-use of tobacco, alcohol, and marijuana. Additionally, other outcomes related to use should be

examined among these individuals to determine if they truly are at lower risk for mental, sexual, and other negative health-related outcomes. Based on the strong focus to combatting substance use and other negative health outcomes, it may be important to not only gain a better understanding of why these individuals are none users, but to determine if services can be provided to these individuals to prevent any future tobacco, alcohol, or marijuana initiation, in addition other health services.

Among users, the resulting combinations of polysubstance use that this study found provides insight to cessation or addiction services on college campuses. Many campuses struggle to identify those at high risk for substance use which are at significant risk for negative health and academic outcomes. Concurrent use of tobacco, alcohol, and marijuana could have additive effects on mental health issues such as anxiety, depression, and suicide ideation while putting students at risk for dependence [135]. Often, mental health issues including those previous listed have serious academic impacts such as lower GPA and increased risk of dropping out [136]. The substances assessed in this study are being used simultaneously as nearly all of the behaviors were comprised of concurrent substance use. While this study did not find specific groups or classes of tobacco users, the introduction of alternative tobacco behaviors in this population proves problematic for addressing tobacco use. In this study, it was observed that for individuals who belonged to classes that had tobacco use, they nearly always were alcohol users who binge drank. This is highly problematic as these individuals may need to be provided specific services or interventions that addresses their alcohol use as most likely, they could be diagnosed as alcohol-dependent. Alcohol dependence, particularly in college populations increases the overall risk for the negative outcomes previously described and in addition for other substance dependence. For many students, a stigma surrounding tobacco, alcohol, and marijuana use exists.

This includes denial of use and beliefs that they invincible and not susceptible to addiction or substance use-related problems. Addressing tobacco, alcohol, and marijuana use problems on campuses needs to take a holistic approach that encompasses all students, but has the ability to provide targeted information or interventions. By doing so, campuses could eliminate many of the issues that plague college students and provide an overall healthier learning environment, while assisting students in developing healthy behaviors that will last for their lifetime.

Figure 3.1. Example latent class model.

X_1 … X_j represent indicators (substance use behaviors) manifested by the latent construct, C (polysubstance use behaviors).

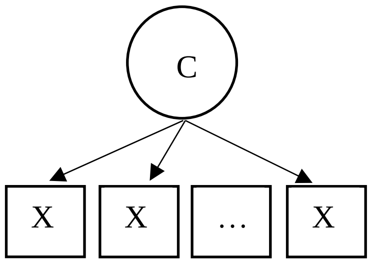


Table 3.1. Frequencies and Study Population Characteristics, NCHA II, Fall 2015

		Entire Sample N=14,504	**Females n=9,926 (68.4%)**	**Males n=4,578 (31.6%)**	**χ^2 p-value**
Student Characteristics		**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	
Age		19.8 (1.54)	19.7 (1.50)	20.0 (1.61)	<0.001
		%	**%**	**%**	
Race	White	70.4	70.3	70.8	
	Black	6.4	6.8	5.5	
	Hispanic	8.0	8.1	7.8	<0.001
	Asian	7.3	6.8	8.4	
	Other	7.9	8.1	7.6	
Year in School	1st	32.3	32.7	31.5	
	2nd	24.5	24.5	24.4	
	3rd	21.3	21.3	21.2	0.02
	4th	16.9	16.8	17.0	
	5th	5.1	4.7	5.6	
Student Housing	On-campus	50.9	51.2	50.4	0.38
Greek System	Yes	14.3	14.8	13.3	0.02
Grade Point Average	A	41.0	41.9	39.1	
	B	48.2	47.9	48.9	0.001
	C	10.1	9.5	11.3	
	D/F	0.7	0.7	0.7	
Students' Institutional Characteristics					
Region	Northeast	25.0	24.6	25.8	0.13
	Midwest	7.8	7.9	7.7	
	South	38.5	39.0	37.2	
	West	28.8	28.5	29.4	
Type	Public	69.8	69.4	70.7	0.10
	Private	30.2	30.6	29.3	
Campus Population	Small: <5,000	27.3	30.0	14.8	<0.001
	Medium/Large: ≥5,000	72.7	70.0	78.5	
Locale Population	Small: <10,000	17.3	18.5	21.5	<0.001
	Medium/Large: ≥10,000	82.7	81.5	85.3	

Table 3.2 Self-Reported Substance Use by Frequency of Use in Last 30 Days, NCHA II, Fall 2015

		Total N=14,504	Females n=9,926 (68.4%)	Males n=4,578 (31.6%)	χ^2 p-value
		%	%	%	
Cigarettes	No use	91.4	93.0	88.1	
	Occasional	5.7	4.7	7.8	<0.001
	Frequent	2.9	2.4	4.1	
Hookah	No use	94.5	95.0	93.6	
	Occasional	4.8	4.5	5.6	0.004
	Frequent	0.7	0.6	0.8	
Cigars	No use	95.2	97.4	90.5	
	Occasional	4.3	2.3	8.7	<0.001
	Frequent	0.5	0.3	0.8	
Electronic Cigarettes	No use	94.8	96.4	91.3	
	Occasional	3.6	2.7	5.5	<0.001
	Frequent	1.6	0.9	3.2	
Alcohol	No use	43.0	42.8	43.6	
	Occasional	44.6	46.1	41.2	<0.001
	Frequent	12.4	11.1	15.2	
Binge Drinking	No use	68.5	71.6	61.6	
	Occasional	13.0	12.9	13.3	<0.001
	Frequent	18.5	15.5	25.1	
Marijuana	No use	83.5	85.0	80.3	
	Occasional	10.8	10.4	11.7	<0.001
	Frequent	5.7	4.6	8.0	

Notes:
Tobacco, alcohol, and marijuana use: use in the last 30 days
No Use: No use or Have used, but not in the last 30 days
Occasional: 1-9 days in the last 30 days
Frequent: 10+ days in the last 30 days
Binge: 5 drinks or more in a sitting
Binge Occasional: 1 or 2 times in last 2 weeks
Binge Frequent: 3 or more times in last 2 weeks

Table 3.3. Results of Latent Class Analysis Model Selection Process, NCHA II, Fall 2015

		2	3	4	5	6	7	8	9	10	# of Classes
Entire Sample	**BIC**	87289.7	85434.9	85147.5	85100.4	85092.4	85132.9	85213.5	85306.2	85408.5	7
	Adj. BIC	87197.6	85295.1	84960.0	84865.3	84809.6	84802.4	84835.3	84880.4	84935.0	
	VMLRT	0.00	0.00	0.00	0.23	0.80	0.01	0.63	0.83	0.76	
	BLRT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Entropy	0.78	0.77	0.78	0.77	0.74	0.75	0.76	0.76	0.78	
Females	**BIC**	55207.9	54316.1	54187.5	54209.5	54268.4	54358.7	54458.5	54559.3	54663.7	6
	Adj. BIC	55115.8	54176.2	54000.0	53974.4	53966.2	54028.9	54080.3	54133.5	54190.2	
	VMLRT	0.00	0.00	0.00	0.01	0.02	0.50	0.79	0.78	0.83	
	BLRT	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.38	
	Entropy	0.75	0.75	0.77	0.75	0.74	0.75	0.78	0.77	0.75	
Males	**BIC**	31500.9	30789.4	30729.3	30739.2	30773.0	30848.2	30935.1	31025.6	31116.7	6
	Adj. BIC	31408.7	30649.6	30541.9	30504.0	30490.2	30517.7	30557.0	30599.8	30643.2	
	VMLRT	0.00	0.00	0.08	0.86	0.64	1.00	0.81	0.90	0.86	
	BLRT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.10	
	Entropy	0.83	0.79	0.81	0.83	0.82	0.85	0.86	0.87	0.76	

Notes:

BIC = Adjusted Bayesian Information Criteria. Looking for lowest value

Adjusted BIC= Sample size adjusted BIC. Looking for lowest value

VMLRT = Vuong Lo-Mendell-Rubin test p-value. Looking for changeover to >0.05. k-1

BLRT = Bootstrapped parametric likelihood ratio test p-value. Looking for changeover to >0.05. k-1

Entropy = Not a model fit statistic, but model classification value >0.70 indicates good classification. Higher value, better classification

Table 3.4. Self-Reported Combinations of Current Polysubstance and Polytobacco Use, NCHA II, Fall 2015

			Entire Sample N=14,504	Females n=9,926 (68.4%)	Males n=4,578 (31.6%)	χ^2 p-value
			%	%	%	
Number of Behaviors		0	39.4	39.5	39.0	
		1	22.7	25.3	16.9	
		2	20.4	20.5	20.1	
		3	9.6	8.9	11.1	
		4	4.8	3.7	7.2	<0.001
		5	2.1	1.5	3.5	
		6	0.8	0.5	1.4	
		7	0.3	0.1	0.8	
Single-Tobacco			14.0	10.6	21.3	<0.001
Dual-Tobacco Use			5.7	3.9	9.5	<0.001
Polytobacco Use			1.7	1.0	3.1	<0.001
Single Tobacco and	Marijuana		12.5	9.5	18.8	<0.001
	Alcohol		6.7	5.1	10.6	<0.001
	Binge Alcohol		9.2	6.3	15.5	<0.001
Dual Tobacco and	Marijuana		3.3	2.4	5.4	<0.001
	Alcohol		5.1	3.5	8.6	<0.001
	Binge Alcohol		4.1	2.5	7.5	<0.001
Polytobacco and	Marijuana		1.2	0.8	2.0	<0.001
	Alcohol		1.6	1.0	2.9	<0.001
	Binge Alcohol		1.3	0.7	2.6	<0.001
Alcohol and Binge			30.1	27.1	36.7	<0.001
Alcohol only			26.8	30.2	19.6	<0.001
Binge only			1.4	1.3	1.6	<0.001

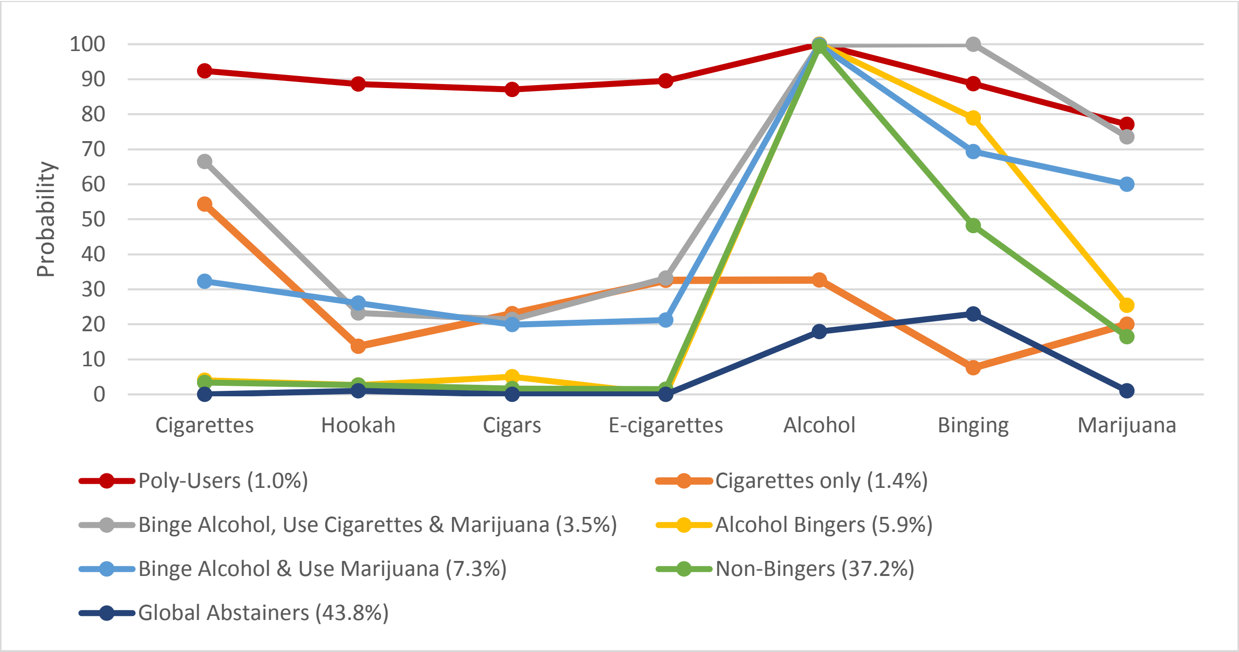
Notes:
Number of behaviors is any (>1 day) substance use or alcohol binging in the last 30 days
Dual Tobacco Use: Any use of 2 or more substances or tobacco products in last 30 days
Polytobacco Use: Any use of 3 or more substances or tobacco products in last 30 days

Table 3.5. Probabilities of Substance Use by Frequency within Latent Classes, Entire Sample, NCHA II, Fall 2015

Class (% of total sample)	Cigarettes		Hookah		Cigars		E-Cigarettes		Alcohol		Binging		Marijuana	
	Occ.	**Freq.**	**Occ.**	**Freq.**	**Occ.**	**Freq.**	**Occ.**	**Freq.**	**Occ.**	**Freq.**	**Occ.**	**Freq.**	**Occ.**	**Freq.**
Class 1 (1.0%)	**48.8**	**43.6**	**70.3**	**18.3**	**69.9**	**17.2**	**63.9**	**25.6**	**53.7**	**46.3**	**17.0**	**71.7**	**35.3**	**41.8**
Class 2 (1.4%)	**27.4**	**26.9**	10.9	2.8	20.2	2.9	17.3	15.3	32.7	0.0	2.7	4.9	6.2	13.8
Class 3 (3.5%)	**41.8**	**24.7**	20.7	2.5	21.4	0.0	23.8	9.4	**6.6**	**93.3**	**6.3**	**93.7**	**34.6**	**38.9**
Class 4 (5.9%)	2.0	2.0	1.7	1.0	4.0	1.0	0.0	0.0	**36.2**	**63.8**	**23.8**	**55.1**	16.2	9.2
Class 5 (7.3%)	24.4	7.9	23.6	2.5	17.9	2.0	14.8	6.4	**81.1**	**18.7**	**28.6**	**40.7**	**39.9**	**20.1**
Class 6 (37.2%)	2.4	1.0	2.7	0.0	1.7	0.0	1.5	0.0	**99.4**	**0.0**	30.1	18.1	13.8	2.7
Class 7 (43.8%)	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	16.0	1.9	1.0	22	1.0	0.0

Class 1	Polysubstance users
Class 2	Cigarettes Only
Class 3	Binge Alcohol, Use Cigarettes & Marijuana
Class 4	Alcohol Bingers
Class 5	Binge Alcohol and Use Marijuana
Class 6	Non-bingers
Class 7	Global abstainers

Figure 3.2. Probability of Substance Use within Latent Classes, Entire Sample, NCHA II, Fall 2015

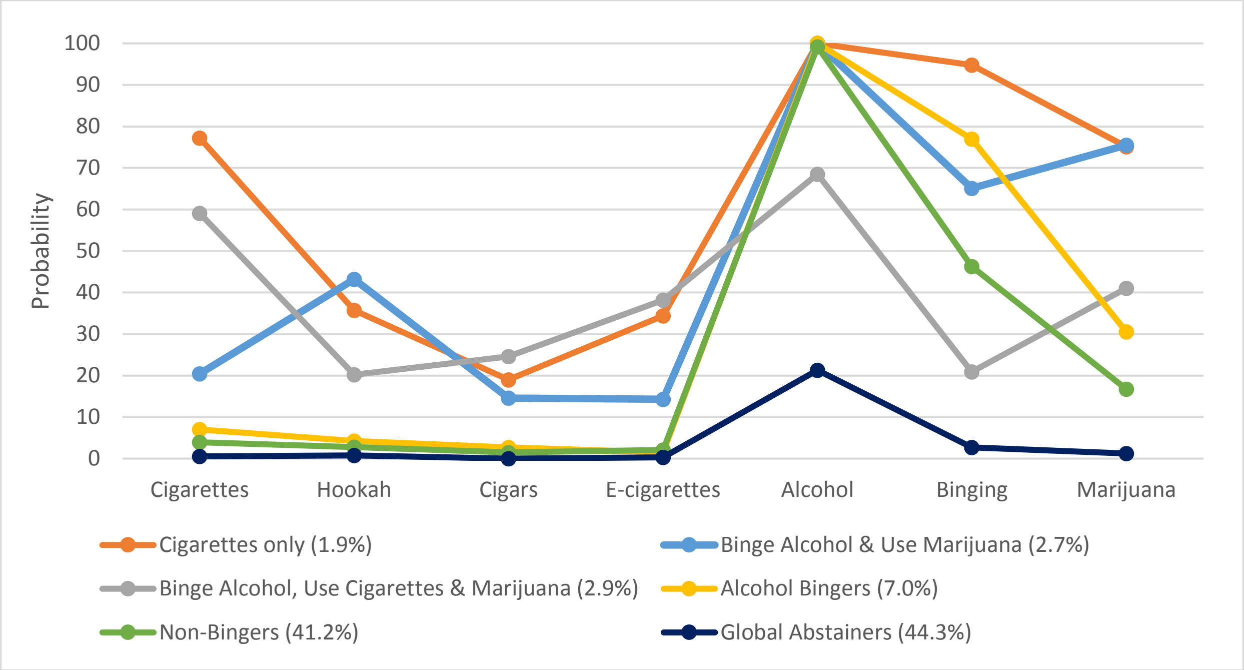


Note: Refer to Table 3.5 for a breakdown of frequency probabilities

Table 3.6. Probabilities of Substance Use by Frequency within Latent Classes, Female Sample, NCHAII, Fall 2015														
Class (% of total sample)	**Cigarettes**		**Hookah**		**Cigars**		**E-Cigarettes**		**Alcohol**		**Binging**		**Marijuana**	
	Occ.	**Freq.**	**Occ.**	**Freq.**	**Occ.**	**Freq.**	**Occ.**	**Freq.**	**Occ.**	**Freq.**	**Occ.**	**Freq.**	**Occ.**	**Freq.**
Class 1 (1.9%)	**32.9**	**26.2**	17.4	2.8	19.3	5.3	25.8	12.4	**68.5**	**0.0**	13.8	7.1	11.7	29.3
Class 2 (2.7%)	19.2	1.2	41.5	1.7	14.6	0.0	12.9	1.4	**79.1**	**20.9**	**30.1**	**35.0**	**61.5**	**14.0**
Class 3 (2.9%)	**48.2**	**29.0**	29.0	6.7	15.9	3.1	25.5	8.9	**26.7**	**73.3**	**12.8**	**82.0**	**40.8**	**34.3**
Class 4 (7.0%)	4.2	2.8	2.8	1.4	2.4	0.3	0.7	0.8	**41.8**	**58.2**	**24.2**	**52.8**	20.1	10.4
Class 5 (41.2%)	3.1	0.8	2.8	0.0	1.4	0.1	1.8	0.3	**99.2**	**0.0**	30.6	15.7	13.8	2.9
Class 6 (44.3%)	0.3	0.2	0.7	0.1	0.0	0.0	0.2	0.1	19.1	2.2	0.6	2.1	0.9	0.3

Class 1	Cigarettes & Alcohol
Class 2	Binge Alcohol and Use Marijuana
Class 3	Binge Alcohol, Use Cigarettes & Marijuana
Class 4	Alcohol Bingers
Class 5	Non-bingers
Class 6	Global abstainers

Figure 3.3. Probability of Substance Use within Latent Classes, Female Sample, NCHA II, Fall 2015



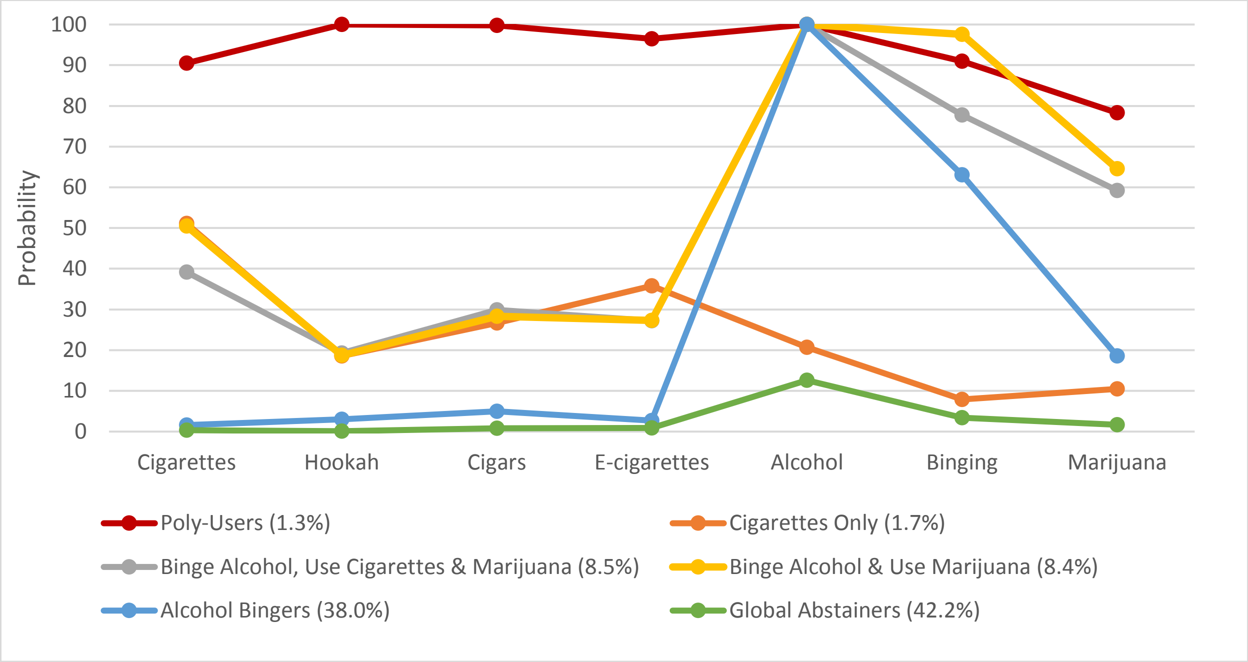
Note: Refer to Table 3.6 for a breakdown of frequency probabilities

Table 3.7. Probabilities of Substance Use by Frequency within Latent Classes, Male Sample, NCHA II, Fall 2015

Class (% of total sample)	Cigarettes		Hookah		Cigars		E-Cigarettes		Alcohol		Binging		Marijuana	
	Occ.	**Freq.**	**Occ.**	**Freq.**	**Occ.**	**Freq.**	**Occ.**	**Freq.**	**Occ.**	**Freq.**	**Occ.**	**Freq.**	**Occ.**	**Freq.**
Class 1 (1.3%)	**51.1**	**39.4**	**82.4**	**17.6**	**84.1**	**15.7**	**68.7**	**27.8**	**50.8**	**49.2**	**14.2**	**76.8**	**34.6**	**43.7**
Class 2 (1.7%)	**26.5**	**24.6**	12.5	6.1	24.1	2.6	12.7	23.1	15.6	5.1	3.8	4.1	5.6	4.9
Class 3 (8.4%)	29.4	9.8	17.4	1.9	26.7	3.2	18.3	8.9	**100.0**	**0.0**	**28.6**	**49.2**	**36.9**	**22.3**
Class 4 (8.5%)	**30.8**	**19.7**	16.5	2.2	28.3	0.0	18.5	8.8	**0.0**	**100.0**	**9.6**	**88.0**	**27.7**	**36.9**
Class 5 (38.0%)	1.6	0.0	2.9	0.1	4.4	0.6	1.4	1.3	**81.2**	**18.8**	**29.7**	**33.4**	14.2	4.4
Class 6 (42.2%)	0.0	0.3	0.1	0.0	0.7	0.1	0.6	0.3	12.6	0.0	1.0	2.4	1.1	0.6

Class 1	Polysubstance users
Class 2	Cigarettes Only
Class 3	Binge Alcohol and Use Marijuana
Class 4	Binge Alcohol, Use Cigarettes & Marijuana
Class 5	Alcohol Bingers
Class 6	Global abstainers

Figure 3.4. Probability of Substance Use within Latent Classes, Male Sample, NCHA II, Fall 2015



Note: Refer to Table 3.7 for a breakdown of frequency probabilities

Table 3.8. Multinomial Regression of Entire Sample with Student and Institutional Characteristics, NCHA II, Fall 2015

		Polysubstance users		Cigarettes only		Binge Alcohol, Use Cigarettes & Marijuana		Alcohol Bingers		Binge Alcohol and Use Marijuana		Non-bingers	
Student Characteristics		**aOR (95% CI)**	**p-value**	**aOR (95% CI)**	**p-value**	**aOR (95% CI)**	**p-value**	**aOR (95% CI)**	**p-value**	**aOR (95% CI)**	**p-value**	**aOR (95% CI)**	**p-value**
Age		0.94 (0.80-1.10)	0.42	**1.16 (1.05-1.27)**	**<0.001**	**1.36 (1.05-1.27)**	**<0.001**	**1.36 (1.28-1.44)**	**<0.001**	**1.52 (1.45-1.59)**	**<0.001**	**1.36 (1.32-1.39)**	**<0.001**
	White (ref)	-	-	-	-	-	-	-	-	-	-	-	-
	Black	0.83 (0.33-2.08)	0.68	0.74 (0.41-1.33)	0.31	**0.31 (0.74-0.54)**	**<0.001**	**0.57 (0.41-0.80)**	**<0.001**	0.72 (0.54-0.95)	0.021	**0.74 (0.64-0.86)**	**<0.001**
Race	Hispanic	0.81 (0.35-1.90)	0.63	0.66 (0.36-1.20)	0.17	0.80 (0.57-1.12)	0.19	0.72 (0.55-0.95)	0.02	0.99 (0.78-1.24)	0.90	0.84 (0.73-0.95)	0.01
	Asian	0.57 (0.24-1.34)	0.20	0.79 (0.48-1.32)	0.37	**0.34 (0.22-0.52)**	**<0.001**	**0.35 (0.25-0.50)**	**<0.001**	**0.40 (0.29-0.54)**	**<0.001**	**0.52 (0.45-0.60)**	**<0.001**
	Other	1.04 (0.49-2.20)	0.91	0.88 (0.53-1.46)	0.61	0.69 (0.48-0.98)	0.04	**0.69 (0.52-0.91)**	**<0.001**	0.94 (0.74-1.18)	0.57	**0.71 (0.62-0.81)**	**<0.001**
	1st (ref)	-	-	-	-	-	-	-	-	-	-	-	-
	2nd	0.94 (0.54-1.64)	0.81	0.73 (0.50-1.05)	0.09	**1.49 (1.14-1.95)**	**<0.001**	**1.72 (1.35-2.18)**	**<0.001**	**1.34 (1.13-1.60)**	**<0.001**	**1.75 (1.58-1.93)**	**<0.001**
Year in school	3rd	1.03 (0.56-1.90)	0.93	1.20 (0.83-1.73)	0.33	**2.74 (2.11-3.56)**	**<0.001**	**3.78 (3.02-4.74)**	**<0.001**	**1.85 (1.54-2.22)**	**<0.001**	**2.83 (2.55-3.15)**	**<0.001**
	4th	1.57 (0.89-3.12)	0.20	1.01 (0.61-1.69)	0.96	**5.05 (3.84-6.66)**	**<0.001**	**10.3 (8.25-12.9)**	**<0.001**	**3.11 (2.54-3.81)**	**<0.001**	**5.74 (5.08-6.48)**	**<0.001**
	5th or more	1.08 (0.33-3.57)	0.90	1.32 (0.63-2.76)	0.46	**4.93 (3.34-7.27)**	**<0.001**	**9.13 (6.70-12.4)**	**<0.001**	**2.55 (1.84-3.52)**	**<0.001**	**4.64 (3.83-5.63)**	**<0.001**
Student Housing	On-campus	1.13 (0.74-1.76)	0.57	0.71 (0.54-0.94)	0.02	**0.66 (0.55-0.79)**	**<0.001**	**0.56 (0.49-0.65)**	**<0.001**	**0.80 (0.70-0.91)**	**<0.001**	**0.78 (0.73-0.84)**	**<0.001**
Greek System	Yes	**5.69 (3.43-9.46)**	**<0.001**	1.47 (0.90-2.41)	0.13	**6.99 (5.63-8.68)**	**<0.001**	**6.65 (5.56-7.95)**	**<0.001**	**3.39 (2.81-4.10)**	**<0.001**	**3.64 (3.22-4.12)**	**<0.001**
	A (ref)	-	-	-	-	-	-	-	-	-	-	-	-
Grade Point	B	**2.41 (1.41-4.12)**	**<0.001**	**2.24 (1.61-3.11)**	**<0.001**	**2.00 (1.62-2.48)**	**<0.001**	**1.65 (1.41-1.93)**	**<0.001**	**1.99 (1.71-2.31)**	**<0.001**	**1.21 (1.12-1.31)**	**<0.001**
Average	C	**3.96 (1.99-7.86)**	**<0.001**	**2.34 (1.42-3.85)**	**<0.001**	**3.14 (2.35-4.19)**	**<0.001**	**2.03 (1.59-2.59)**	**<0.001**	**3.24 (2.63-4.00)**	**<0.001**	**1.22 (1.06-1.40)**	**<0.001**
	D/F	**12.5 (3.49-44.5)**	**<0.001**	**8.87 (3.58-22.0)**	**<0.001**	**3.92 (1.71-9.02)**	**<0.001**	0.82 (0.25-2.67)	0.74	**4.61 (2.55-8.33)**	**<0.001**	1.01 (0.62-1.68)	0.96
Institutional Characteristics													
	Midwest	**2.80 (1.35-5.84)**	**<0.001**	0.99 (0.52-1.86)	0.97	**1.77 (1.23-2.54)**	**<0.001**	**1.91 (1.43-2.55)**	**<0.001**	**1.92 (1.49-2.48)**	**<0.001**	**2.01 (1.73-2.33)**	**<0.001**
Region	Northeast	1.49 (0.81-2.76)	0.20	1.41 (0.97-2.05)	0.07	**1.51 (1.17-1.96**	**<0.001**	**1.68 (1.36-2.06)**	**<0.001**	**1.68 (1.40-2.02)**	**<0.001**	**1.81 (1.63-2.01)**	**<0.001**
	South	1.44 (0.82-2.52)	0.20	1.13 (0.79-1.63)	0.50	**1.67 (1.33-2.11)**	**<0.001**	**1.68 (1.40-2.02)**	**<0.001**	**1.93 (1.61-2.32)**	**<0.001**	**1.59 (1.34-1.88**	**<0.001**
	West (ref)	-	-	-	-	-	-	-	-	-	-	-	-
Type	Public	0.77 (0.49-1.23)	0.28	0.92 (0.68-1.23)	0.56	1.29 (1.05-1.60)	0.02	1.06 (0.90-1.24)	0.47	1.00 (0.87-1.15)	0.98	0.97 (0.90-1.05)	0.51
Campus Population	Small	0.86 (0.50-1.48)	0.58	1.16 (0.85-1.57)	0.35	**0.74 (0.59-0.93)**	**<0.01**	0.86 (0.72-1.02)	0.08	0.89 (0.77-1.04)	0.14	1.04 (0.96-1.13)	0.34
Locale Population	Small	**0.33 (0.15-0.72)**	**<0.001**	0.91 (0.60-1.40)	0.68	0.79 (0.60-1.03)	0.08	0.81 (0.66-1.00)	0.05	0.79 (0.65-0.96)	0.02	0.95 (0.86-1.06)	0.34

Notes:
All models controlled for gender and institution identification number
Global abstainer group is class solution reference for all models
Odds ratios and p-values in bold are significant
P-value significance level = 0.001 due to multiple testing correction

Table 3.9. Multinomial Regression of Female Sample with Student and Institutional Characteristics, NCHA II, Fall 2015

Student Characteristics		Cigarettes only aOR (95% CI)	p-value	Binge Alcohol and Use Marijuana aOR (95% CI)	p-value	Binge Alcohol, Use Cigarettes & Marijuana aOR (95% CI)	p-value	Alcohol Bingers aOR (95% CI)	p-value	Non-bingers aOR (95% CI)	p-value
Age		**1.15 (1.04-1.27)**	**<0.001**	1.11 (1.02-1.22)	0.02	**1.31 (1.21-1.42)**	**<0.001**	**1.53 (1.45-1.61)**	**<0.001**	**1.39 (1.34-1.43)**	**<0.001**
Race	White (ref)	-	-	-	-	-	-	-	-	-	-
	Black	**0.44 (0.20-0.94)**	**<0.001**	0.81 (0.49-1.35)	0.42	**0.25 (0.11-0.57)**	**<0.001**	0.76 (0.55-1.06)	0.10	**0.79 (0.66-0.93)**	**<0.001**
	Hispanic	0.81 (0.46-1.41)	0.55	1.15 (0.76-1.74)	0.51	1.13 (0.76-1.67)	0.55	0.83 (0.62-1.12)	0.23	**0.78 (0.66-0.92)**	**<0.001**
	Asian	0.60 (0.32-1.12)	**<0.001**	**0.40 (0.22-0.75)**	**<0.001**	**0.43 (0.24-0.75)**	**<0.001**	**0.45 (0.31-0.65)**	**<0.001**	**0.49 (0.41-0.58)**	**<0.001**
	Other	1.03 (0.64-1.67)	0.41	0.99 (0.95-1.51)	0.96	0.84 (0.55-1.28)	0.41	**0.64 (0.46-0.88)**	**<0.001**	**0.65 (0.55-0.76)**	**<0.001**
Year in school	1st (ref)	-	-	-	-	-	-	-	-	-	-
	2nd	1.25 (0.86-1.81)	0.17	0.45 (1.05-1.99)	0.03	1.25 (0.90-1.75)	0.17	**1.69 (1.31-2.19)**	**<0.001**	**1.83 (1.54-1.94)**	**<0.001**
	3rd	**1.82 (1.24-2.66)**	**<0.001**	1.56 (1.10-2.22)	0.01	**1.58 (1.12-2.24)**	**<0.001**	**3.27 (2.55-4.19)**	**<0.001**	**2.82 (2.50-3.19)**	**<0.001**
	4th	1.62 (0.97-2.71)	**<0.001**	**2.62 (1.78-3.84)**	**<0.001**	**3.82 (2.71-5.38)**	**<0.001**	**9.31 (7.27-11.9)**	**<0.001**	**5.52 (4.78-6.38)**	**<0.001**
	5th or more	1.71 (0.77-3.80)	**<0.001**	2.10 (1.12-3.96)	0.02	**2.28 (1.24-4.22)**	**<0.001**	**7.55 (5.27-10.8)**	**<0.001**	**4.17 (3.31-5.25)**	**<0.001**
Student Housing	On-campus	**0.69 (0.52-0.93)**	**<0.001**	0.99 (0.78-1.28)	0.96	**0.68 (0.54-0.87)**	**<0.001**	**0.61 (0.51-0.71)**	**<0.001**	**0.81 (0.74-0.88)**	**<0.001**
Greek System	Yes	0.73 (0.38-1.39)	**<0.001**	**1.99 (1.37-2.90)**	**<0.001**	**4.06 (3.01-5.46)**	**<0.001**	**5.62 (4.60-6.87)**	**<0.001**	**3.43 (2.98-3.94)**	**<0.001**
Grade Point Average	A (ref)	-	-	-	-	-	-	-	-	-	-
	B	**1.94 (1.37-2.75)**	**<0.001**	**1.84 (1.39-2.44)**	**<0.001**	**2.32 (1.74-3.09)**	**<0.001**	**1.54 (1.29-1.84)**	**<0.001**	**1.18 (1.08-1.29)**	**<0.001**
	C	**3.81 (2.43-5.98)**	**<0.001**	**2.69 (1.80-4.04)**	**<0.001**	**3.43 (2.31-5.08)**	**<0.001**	**2.21 (1.69-2.89)**	**<0.001**	1.19 (1.01-1.40)	0.03
	D/F	**11.8 (4.83-28.7)**	**<0.001**	3.19 (0.94-10.9)	0.09	**7.01 (2.77-17.8)**	**<0.001**	1.82 (0.69-4.84)	0.23	1.24 (0.70-2.20)	0.46
Institutional Characteristics											
Region	Midwest	0.79 (0.39-1.63)	0.53	**2.30 (1.45-3.63)**	**<0.01**	1.45 (0.90-2.33)	0.12	**1.89 (1.36-2.62)**	**<0.01**	**1.81 (1.52-2.15)**	**<0.001**
	Northeast	**1.59 (1.07-2.38)**	**0.02**	**1.96 (1.38-2.79)**	**<0.01**	**1.64 (1.18-2.29)**	**<0.01**	**1.71 (1.34-2.18)**	**<0.01**	**1.81 (1.60-2.05)**	**<0.001**
	South	1.30 (0.89-1.89)	0.18	**1.61 (1.16-2.23)**	**<0.01**	1.20 (0.88-1.63)	0.26	**2.05 (1.67-2.53)**	**<0.01**	**1.89 (1.70-2.11)**	**<0.001**
	West (ref)	-	-	-	-	-	-	-	-	-	-
Type	Public	0.86 (0.64-1.17)	0.34	0.99 (0.76-1.30)	0.95	1.00 (0.77-1.30)	0.97	1.24 (1.03-1.49)	0.02	1.05 (0.96-1.16)	0.30
Campus Population	Small	0.80 (0.57-1.11)	0.18	1.00 (0.76-1.32)	0.98	**0.72 (0.54-0.95)**	**0.02**	**0.77 (0.64-0.93)**	**<0.001**	0.99 (0.90-1.09)	0.86
Locale Population	Small	0.94 (0.61-1.46)	0.79	0.71 (0.49-1.02)	0.06	0.88 (0.63-1.23)	0.45	0.90 (0.71-1.13)	0.35	1.02 (0.90-1.15)	0.79

Notes:
All models controlled for institution identification number
Global abstainer group is class solution reference for all models
Odds ratios and p-values in bold are significant
P-value significance level = 0.001 due to multiple testing correction

Table 3.10. Multinomial Regression of Male Sample with Student and Institutional Characteristics, NCHA II, Fall 2015

Student Characteristics		Polysubstance users aOR (95% CI)	p-value	Binge Alcohol, Use Cigarettes & Marijuana aOR (95% CI)	p-value	Binge Alcohol and Use Marijuana aOR (95% CI)	p-value	Cigarettes only aOR (95% CI)	p-value	Alcohol Bingers aOR (95% CI)	p-value
Age		0.84 (0.69-1.03)	0.09	**1.34 (1.28-1.40)**	**<0.01**	**1.14 (1.07-1.23)**	**<0.001**	**1.32 (1.24-1.41)**	**<0.001**	0.98 (0.83-1.14)	0.75
Race	White (ref)	-	-	-	-	-	-	-	-	-	-
	Black	0.91 (0.32-2.59)	0.86	**0.56 (0.42-0.76)**	**<0.001**	0.80 (0.50-1.28)	0.34	**0.42 (0.24-0.75)**	**<0.001**	0.78 (0.28-2.18)	0.69
	Hispanic	0.79 (0.28-2.23)	0.65	0.89 (0.70-1.13)	0.34	1.24 (0.86-1.80)	0.26	**0.42 (0.25-0.71)**	**<0.001**	0.66 (0.24-1.86)	0.43
	Asian	0.51 (0.18-1.43)	0.20	**0.52 (0.41-0.66)**	**<0.001**	**0.36 (0.22-0.61)**	**<0.001**	**0.24 (0.14-0.43)**	**<0.001**	1.27 (0.65-2.48)	0.49
	Other	0.87 (0.31-2.47)	0.80	0.94 (0.73-1.21)	0.61	1.28 (0.87-1.88)	0.22	0.87 (0.57-1.31)	0.50	1.29 (0.57-2.90)	0.54
Year in school	1st (ref)	-	-	-	-	-	-	-	-	-	-
	2nd	0.98 (0.51-1.89)	0.95	**1.80 (1.50-2.16)**	**<0.01**	1.15 (0.85-1.54)	0.38	**1.81 (1.29-2.54)**	**<0.001**	0.63 (0.35-1.11)	0.11
	3rd	1.00 (0.47-2.12)	0.99	**3.08 (2.54-2.73)**	**<0.01**	**1.97 (1.45-2.67)**	**<0.01**	**4.26 (3.08-5.89)**	**<0.001**	0.53 (0.56-1.10)	0.08
	4th	1.50 (0.64-3.55)	0.35	**7.11 (5.59-8.87)**	**<0.01**	**3.27 (2.32-4.60)**	**<0.01**	**6.68 (4.67-9.57)**	**<0.001**	0.37 (0.11-1.21)	0.10
	5th or more	1.14 (0.26-5.96)	0.86	**6.87 (4.92-9.59)**	**<0.01**	**2.72 (1.58-4.66)**	**<0.01**	**7.48 (4.58-12.2)**	**<0.001**	1.04 (0.31-3.47)	0.95
Student Housing	On-campus	1.14 (0.67-1.94)	0.62	**0.67 (0.59-0.92)**	**<0.01**	**0.74 (0.59-0.92)**	**<0.01**	**0.62 (0.50-0.77)**	**<0.001**	1.09 (0.68-1.73)	0.72
Greek System	Yes	**8.64 (4.59-16.3)**	**<0.001**	**4.71 (3.64-6.10)**	**<0.01**	**5.34 (4.54-8.83)**	**<0.01**	**12.2 (8.97-16.6)**	**<0.001**	**3.20 (1.54-6.66)**	**<0.001**
Grade Point Average	A (ref)	-	-	-	-	-	-	-	-	-	-
	B	**2.48 (1.32-4.65)**	**<0.001**	**1.36 (1.18-1.56)**	**<0.01**	**2.08 (1.59-2.72)**	**<0.01**	**2.24 (2.73-2.89)**	**<0.01**	**2.23 (1.30-3.82)**	**<0.001**
	C	**3.25 (1.38-7.63)**	**<0.001**	**1.37 (1.08-1.74)**	**<0.01**	**4.20 (2.97-5.94)**	**<0.01**	**3.42 (2.41-4.87)**	**<0.01**	1.80 (0.75-4.33)	0.18
	D/F	<0.01 (<0.01- >999)	0.96	0.73 (0.29-1.87)	0.52	**0.73 (0.29-1.87)**	**<0.01**	2.05 (0.57-7.40)	0.27	6.90 (1.45-32.9)	0.02
Institutional Characteristics											
Region	Midwest	**3.67 (1.44-9.36)**	**<0.001**	**2.84 (2.16-3.73)**	**<0.001**	**1.54 (0.96-2.47)**	0.07	**2.41 (1.56-3.73)**	**<0.001**	0.87 (0.25-2.95)	0.81
	Northeast	1.48 (0.67-3.25)	0.32	**1.88 (1.56-2.25)**	**<0.001**	1.29 (0.95-1.75)	0.10	1.41 (1.03-1.92)	0.03	1.46 (0.79-2.69)	0.22
	South	**2.20 (1.12-4.32)**	**0.02**	**1.85 (1.55-2.20)**	**<0.001**	**1.46 (1.10-1.94)**	**<0.001**	**1.84 (1.39-2.44)**	**<0.001**	1.33 (0.74-2.42)	0.80
	West (ref)	-	-	-	-	-	-	-	-	-	-
Type	Public	0.95 (0.53-1.71)	0.86	**0.83 (0.72-0.95)**	**<0.001**	0.93 (0.73-1.18)	0.52	1.28 (0.99-1.65)	0.06	0.79 (0.48-1.29)	0.35
Campus Population	Small	0.96 (0.49-1.88)	0.91	1.13 (0.97-1.32)	0.13	1.09 (0.84-1.13)	0.52	0.85 (0.64-1.13)	0.26	1.27 (0.75-2.17)	0.37
Locale Population	Small	0.43 (0.18-1.02)	0.06	0.80 (0.66-0.98)	0.11	0.65 (0.46-0.93)	0.03	**0.58 (0.41-0.83)**	**<0.001**	0.53 (0.24-1.17)	0.12

Notes:
All models controlled for institution identification number
Global abstainer group is class solution reference for all models
Odds ratios and p-values in bold are significant
P-value significance level = 0.001 due to multiple testing correction

CHAPTER 4a: Tobacco/E-cigarette Availability around College Campuses and in Neighborhoods of Richmond, VA

ABSTRACT

Background: It is established that restricting tobacco retailer density or proximity distance to K-12 schools can reduce youth smoking. Based on known spatial patterns of tobacco use in communities, similar restrictions could reduce smoking on college campuses. Currently, there is a lack of information on where tobacco and e-cigarettes products are sold within communities and around college campuses. Retailer data locations from e-cigarette brand websites could be used to analyze geospatial locations of tobacco/e-cigarette retailers.

Objective: Examine spatial tobacco/e-cigarette retailer locations in close proximity to college campuses testing the relationship between the availability of tobacco products and neighborhood-based socioeconomic status (SES).

Methods: Location addresses were collected for six popular e-cigarette brands within the Richmond, Virginia Metropolitan Statistical Area (RVMSA). Tobacco/e-cigarette retailer location data were merged with collected data on eleven college campuses in the RVMSA. The primary outcome was retailer counts within a half-mile, 1-mile and 2-miles (Euclidean radii) of each campus to examine the neighborhoods surrounding the institutions. Additional outcomes of retailer count and density within census tracts were also examined. Associations between the number of retailers and neighborhood- level SES measures were tested using negative binomial regression including: racial/ethnic diversity of the neighborhoods and tract-level SES.

Results: A total of 984 tobacco/e-cigarette retailers were found in the RVMSA, with an overall density of 0.19 retailers per 10km of roadway (county-level range: 0.01-1.03). There were 95 retailers within a half-mile of the eleven college campuses, 219 within one mile, and 384 within two miles. Statistical differences were not performed due to the small number of campuses,

however average retailer density was much higher for campuses in Richmond City. For neighborhoods, those living in the lowest SES census tracts had a significantly higher retailer density than high SES neighborhoods. Specifically, retailer density was higher in neighborhoods with lower household income and value and higher unemployment and poverty.

Conclusions: Retailer density was much higher in low SES areas of the RVMSA. Colleges also had a large number of retailers surrounding campuses, indicating that students in the area have access to tobacco products. The examination of multiple distances proved necessary as under two miles, as on average there were 30 retailers surrounding each campus. The highest overall average was for campuses within Richmond City.

INTRODUCTION

Background

Tobacco availability can be defined as the tobacco retail environment within a neighborhood or community and is known to influence socioecological aspects of tobacco use directly. Examples of these aspects include altering the social acceptability in the community environment, influencing initiation and continuation of use among youth and young adults [137,138], and directly impacting the success of an individual's cessation attempts [139,140]. Retailers not only sell products [141], but many locations contain extensive advertising on the inside and outside intended to alter the community normative and attract new users [142-144]. Specific subgroups or potential users are often targeted by the tobacco industry through the retail environment [145]. Tobacco often is located disproportionately in low socioeconomic areas of communities, localities with higher prevalence of non-white population groups generally have higher retail density, and retailers are more concentrated in neighborhoods where individuals tend to be less healthy and have worse health outcomes [146-149]. Youth populations are often thought to be the most vulnerable to tobacco availability, particularly in regard to initiation [7,150,151]. Studies assessing tobacco availability examine the influence of availability on prevalence of use in youth populations, however college students are influenced by a multitude of socioecological aspects including tobacco availability [152,153]. From the perspective of the socioecological model for tobacco control for college students, little to no research has examined the extent of tobacco availability around campuses. Additionally, previous research has established that higher retailer density or proximity to retailers is associated with higher rates of smoking and initiation by youth and young adults, in addition to lower success of cessation attempts [137,144,154,155].

Socioecological Model Related to Tobacco Availability among College Populations

The use of a socioecological model of tobacco behaviors in college students provides an opportunity to examine different aspects of use [23,78]. Socioecological models are a framework often used in prevention research. These models consider the complex relationships that occur between individual, relationship, community, and societal factors. As demonstrated in Appendix A, each level is adaptable and can encompass similar factors more related to tobacco prevention. The factors being examined in this dissertation include: policy/regulation, community environment, personal environment, and personal choice/behaviors [37,38]. Tobacco availability is an aspect of the community environment and is also interrelated with other factors. During the college period, students are exposed to increased tobacco use among college peers [11], have opportunities for use of tobacco during social gatherings [81,113], and have access to purchase products upon turning 18 in most states [152]. Moreover, college students gain new mobility, resulting in freedom to explore their community environments or neighborhoods, which contain retailers selling products. Although an individuals' community environment plays an important role in their health, college populations likely are overlooked due to the relatively short time they spend in that community (4 years or less). Recent national and institutional-based system initiatives such as the Tobacco Free College Campus Initiative (tobaccofreecampus.org) have brought attention to on-campus use of tobacco, however attention is directed toward reducing college student smoking by going tobacco-free as a way to denormalize use. The focus is meant to decrease use on-campus, but most likely has very little effect on the overall campus community (i.e. decrease overall use among the college population) [156]. No addressing off-campus use is problematic as not all students live directly on college campuses as many are residents of the neighborhood communities surrounding a campus. Therefore, availability around

campuses is not just a college health problem, but a community health issue. Additionally, many campuses are now enforcing smoke- or tobacco-free policies that do not allow the sale or purchase of tobacco products on campus, however students seeking to buy tobacco will turn to purchasing in the community environment directly surrounding the campus. To address availability around campuses better, understanding where and how close to campus these products are being sold could be an important policy-based approach to addressing tobacco use in college populations.

Tobacco Availability in Neighborhoods and surrounding College Campuses

Few studies have examined tobacco availability in neighborhoods surrounding colleges and universities [39]. Studies have assessed relationships between educational institutions and tobacco availability but these studies often use primary or secondary K-12 schools and do not take college campuses into account [138,157,158]. The reason for such an omission could be two-fold: first, to properly examine the relationship a sufficient sample size of college campuses, including two- and four-year institutions would be required; and second, to obtain the needed sample size, multiple states may need to be included in the assessment. Such a sample size requirement would be problematic as states often have differing tobacco-based policies and many localities have different sociocultural factors that influence use, potentially creating confounding effects in the assessment. These studies also do not assess the relationship between tobacco availability and the neighborhood environment where campuses are located. For policy purposes, the lack of information on the surrounding neighborhood environment presents issues as decision-making and urban planning (such as commercial zoning), are done at local levels and cannot effectively target the individuals who are most vulnerable.

Spatial patterns of community tobacco use are related to retailer density or overall number of retailers within a locality or defined area [159,160]. Research related to retailer density and associated with youth and adult smoking rates is very well established [34,137,161], particularly in places lacking clean-air (smoke- and tobacco-free) policies [155]. Higher education institutions are of interest as density and proximity of retail outlets influences young adult smoking behaviors [138,162]. Furthermore, smoking prevalence is higher among disadvantaged groups as uptake and cessation rates are often higher among those with lower socioeconomic status [149,163]. Health disparities among low income groups have initiated research to begin to examine the effects of the neighborhood environment. Results indicate that an established relationship between neighborhood tobacco availability and smoking exists with SES as a moderating effect between availability and tobacco use [154,159,162]. However, little research has examined how neighborhood socioeconomic status may be associated with tobacco availability directly, particularly for neighborhoods containing college campuses. Additionally, census tracts with higher percentages of African Americans or Hispanics have an increased percentage of stores that sell tobacco products in their neighborhoods [164] and these neighborhoods often have worse health outcomes [149]. Information on availability could serve as a community health indicator and a potential point of regulation for policies affect neighborhood health.

Previous research on tobacco availability in relation to higher education institutions often has important limitations [39,148]. First, many of these studies are product validation studies. Product validation studies are observational studies that assess which products are carried in retail stores. They can provide spatially precise and accurate data however, are time and resource intensive which often limits their overall study area and thus the number of retailers examined in areas directly surrounding the campuses. Additionally, they do not take into account other areas

of the locale beyond the surrounding campus [39,165]. Second, many studies often look at national- or state-level availability by randomly selecting localities such as counties or metropolitan statistical areas. While studies can be generalized to other localities, every locality has various social and economic influences that affect availability and use, making policy decisions difficult for local policy makers [137,144]. Lastly, states that do not monitor tobacco/e-cigarette retailers present a challenge as available spatial and geographic data on retailers do not exist. To overcome the lack of tobacco availability data, a recent study collected retailer data at the national level by creating a list of "likely" tobacco retailers using the 2012 North American Industry Classification Systems (www.naics.com) of all supermarkets, grocery stores, convenience stores, alcohol retailers, drug stores/pharmacies, tobacco retailers, and gas stations with convenience stores [137]. The broad approach used by Cantrell et al. attempts to create a database of locations, however lacks the precision needed for informed policymaking, particularly at the state or local level. Furthermore, even with established research demonstrating the relationship between availability and smoking, some localities and states do not monitor or license retailers. For example, in Virginia, tobacco licensure is conducted at the distributor level, a step above the retail outlet within the supply chain [166], resulting in a lack of knowledge for policymakers on where products are sold.

Innovation

The recent rise in popularity of e-cigarettes has created a new dimension in the tobacco market and provides an opportunity to assess where e-cigarettes and other tobacco products are sold. Recently, Wagoner et al. reported that e-cigarettes are available widely in tobacco shops, pharmacies, convenience stores, and gas stations [39]. Popular brands such as Blu or NJOY e-cigarettes list retailer locations where products are sold directly on their websites, which has the

potential to be a primary source of information. E-cigarettes are directly marketed toward young adult and youth populations through advertisements on social media and other internet mediums. Young adult or youth populations are known to search for product information online and could search for where products are being sold through brand websites [167-169]. Additionally, proximity to colleges and universities may demonstrate the extent of product availability to young adult populations.

Study Purpose and Aims

The main purpose of this study is to assess tobacco availability in the neighborhood environment surrounding colleges and universities in the Richmond, VA Metropolitan Statistical Area (MSA). The aims of this study are to: 1) describe tobacco availability in the Richmond MSA in relation to higher education institutions, 2) determine density and counts of tobacco/e-cigarette retailer shops in census tract and county-equivalent boundaries of the Richmond, Virginia MSA, 3) describe tobacco availability neighborhoods in the Richmond MSA and in particular, those around colleges and universities, and 4) assess the relationship between tobacco/e-cigarette retailers using counts and density in the Richmond Metropolitan Statistical Area (MSA) and SES, in addition to proximity to universities/colleges. Tobacco density is hypothesized to be higher surrounding college and university campuses and higher in lower SES census tracts.

METHODS

Study Area

The study area for this project is the Richmond, VA MSA. The Richmond MSA is located in the eastern-central Virginia comprising 13 counties and 4 equivalent principal cities

(Table 1) [170]. The total land area is approximately 4,600 square miles with a population of approximately 1.2 million people [170]. Based on population, the Richmond MSA is 45th largest according to the US Census Bureau[171] and the locality overall is highly diverse.

Data Collection

Location of retailers were collected directly from six websites of popular e-cigarette brands and from two additional websites by name, street address, city, and zip code. E-cigarette brand websites were used as a proxy for where tobacco products are sold as Virginia does not license retailers and therefore does not have a database of retailers. Brands were selected based on the results in previous studies [172,173], those shown to be popular among young people [174], those that had provided map-based website location finders. Brands included: Blu, NJOY, V2, Green Smoke, VUSE, and MarkTen. Two additional websites including Yelp.com and Google.com were used to capture non-traditional tobacco/e-cigarette retailers such as vape shops. Embedded location finders on the brand websites provide addresses within a website-specified distance from an entered zip code. During two weeks in early January 2016 the data were web-scraped (copied and pasted) from e-cigarette brand websites by entering zip codes in the Richmond MSA, aggregated, and cleaned in Microsoft Excel spreadsheets to remove duplicate locations.

Census tract and county shapefiles for the Richmond, MSA were obtained from Census TIGER/Line [175]. There is a total of 288 census tracts in the Richmond, VA MSA. Census-tract level data were obtained from the 2014 American Community Survey for socioeconomic and race variables. For colleges and universities in the MSA, institutional data were collected directly from institutional reports found on each institution's website or reports from the most recent data available from the State Council of Higher Education for Virginia (SCHEV). The Virginia

Commonwealth University Institutional Review Board deemed the current study exempt as it utilizes non-human secondary data.

Geocoding

Addresses for retailers and universities/colleges were geocoded using ArcGIS 10.4 [176]. Only geocoded address points or street addresses were accepted as viable points. Based on the geocoded points, a total of 1,365 retailers were collected using the zip codes. Using ArcGIS, all 1,365 points were spatially joined and only those within the Richmond MSA were kept resulting in 984 distinct retailers. Google Street View was then used to validate 50% of locations to ensure precision and accuracy of geocoding. Point shapefiles were created for college campuses and retailer outlets using the North American Datum of 1983 (NAD 83) State Plane (2011) Virginia South projection.

Measures

Retailers

For each retailer, name, address, city, state, and zip code were collected. Additional variables were added for brands collected. To estimate the distribution of retailers across the Richmond MSA, three outcomes were evaluated: tract count, tract density, and campus proximity count (campus retailer density). Retailer tract count refers to the number of retailers that Fall within a census tract. A tract density measure of retailer count within each census tract was calculated. Density was calculated as the number of retailers per ten kilometers of roadway using a shapefile obtained with county and census tract shapes from TIGER/line. The tract density measure accounts for both land area and population density and has previously been used [154,177]. College campus proximity count (campus retailer density) was assessed using three

distances (half-, one-, and two-miles) and two types of buffers (multi-ring neighborhood and entire neighborhood) resulting in five distinct proximity measures related to the campus' location and explained within the *Proximity Measures and Buffers Around Educational Institutions* sub-section within the current section (*Measures*). The use of proximity counts within buffers around each college campus can be considered a density measure rather than a count as the counts are within a specified buffer distance, which is a form of land area as the buffer creates a radius surrounding each campus.

County-Equivalents and Census Tracts

Using data from the 2014 American Community Survey (ACS), data collected for county-equivalents and census tracts included demographic information such as population total, racial composition, and socioeconomic-based variables. SES status variables were selected based on previous literature for creation of an SES index using principal components of a factor analysis at the census tract-level [178,179]. The variables selected were: percent unemployed, percent below poverty threshold, percent less than high school education, percent college education or higher, median household value, and median household income. Variables were standardized and a factor analysis was used to create factor scores that were then divided into quartiles. Lastly, a race diversity index was created based on previous work [180,181] and was recoded as a three-level variable based on the predominant race within a census tract. Race was recoded as a three-level variable because within census tract data, racial groups are given as proportions in separate variables. The race diversity index provided the ability to analyze racial groups as levels of a single variable. The race diversity index was assessed by tracts containing >60% White indicating the tract is majority White, >60% Non-white which indicates that the tract is majority non-White, or less than 60% of both indicating the tract is racially diverse.

Higher Education Institutions

For institutions of higher education, variables included: name, address, student population, institution racial composition, and spatially joined neighborhood SES (census tract where institution is located). The small number of institutions in the Richmond MSA (11) limits the ability to analyze differences in neighborhood availability between institutions. Due to the small sample size, student population and institution racial composition were included in data collection, but only for descriptive purposes. The higher education institutions were not included in the formal analyses, including regression models, beyond descriptive statistics.

Proximity Measures and Buffers around Educational Institutions

To measure proximity counts (density surrounding college campuses), Euclidean radial buffers were created from a centroid of each higher education institution. Euclidean radial buffers are a user determined, straight-line distance measured from a center point where proximity counts are then determined for all points (retailers) Falling within the radial buffer. For this study, three buffer distances of half-, one-, and two-miles were created. Based on previous work, the half-mile buffer appears to be the most commonly used distance concerning retailers as it would be about a ten-minute walk [94,182,183]. One- and two mile buffers were selected to be used for purposes of describing the neighborhood surrounding colleges. Two types of buffers were applied at each distance, whole radius and multi-ring (concentric) buffers (Figure 1). Whole radius buffers cover the entire distance of each buffer (i.e. 0-0.5 mile, 0-1 mile, and 0-2 miles). The multi-ring or concentric buffers cover area excluding the smaller buffers (i.e. 0-0.5 mile, >0.5-1 mile, >1-2 miles). The difference between these types of buffers is that retailer counts within neighborhoods using multi-ring buffers would be mutually exclusive between buffer sizes, whereas for whole radius buffers, results would not be mutually exclusive and retailers

could be counted up to three times when examining larger buffers. College campus-based buffers also may cross-over other campus buffers if they are within two miles of each other, which could result in some retailers being counted multiple times. As an example, if a retailer was found to be within a half-mile of a campus, that same retailer would then be counted two more times in the one- and two-mile whole radius buffers. If the same retailer was within a half-mile of three campuses, the retailer would be counted up to three times for multi-ring buffers and up to nine times for whole radius buffers for all three distances. The created buffers were spatially joined with the retailer dataset to provide a count of the number of retailers within each buffer. None of the buffers overlapped with each other for the college campuses or overlapped outside of the study area, but some did cross over county or census tract boundaries. To avoid confusion with the buffers, the multi-ring buffers will be referred to as half-mile neighborhood (<0.5 mile), one-mile neighborhood (>0.5- 1 mile), and two-mile neighborhood (>1-2 mile) whereas the whole radius buffers will be referred to as half-, one-, and two-mile buffers.

Analysis

Descriptive statistics

Descriptive statistics were assessed at county and census tract levels for the entire Richmond MSA including retailer count, retailer density in tracts (retailers per ten-kilometers of roadway), population per retailer, mean number of retailers per census tract, and population demographics (population density, SES index, and race). As a result of collecting retailer location from brand websites, brand counts by county were also determined.

Descriptive statistics surrounding higher education campus locations were examined including retailer counts in neighborhoods surrounding each campus using both buffer types,

whole and multi-ring buffers, at half-, one-, and two-miles. Campus locations were joined spatially (merged) with census tract information to obtain a tract-level SES index value and tract retailer density. Census tracts adjacent to campuses were also evaluated by assessing the number retailers in adjacent census tracts. However, campuses in rural areas often had misshapen census tracts because census tract lines are drawn to create tract areas with approximately equal population size. The resulting selected census tracts were extremely large areas surrounding rural campuses, which could provide biased increased counts in comparison to more urban campuses. Therefore, examination of counts of retailers at the tract level was not used.

Bivariate and Multivariate Analyses

Bivariate analysis examining retailer counts and density was initially conducted for census tracts and higher education institutions separately. During these comparisons, higher education institutions were unable to be assessed due to small numbers (n=11). For census tracts, the average number of retailers by tract SES index quartiles and tract racial diversity index were examined using Bonferroni Pairwise Comparisons to control for Type 1 error. Type 1 error can occur when comparing differences between more than two means within a single variable (e.g. SES index is split into quartiles, thus has a mean value for each quartile) producing statistically significant differences, when they do not exist. ANOVA was used to perform the bivariate analysis via the PROC ANOVA procedure in SAS 9.4. PROC ANOVA displays average means and determines if there is a statistically significant difference between levels of each variables.

Multivariate analyses were conducted for census tracts. Two separate regression analyses were conducted two for census tracts (counts and density). The regression analyses examined the relationship between availability (counts and density) and SES and race. Two dependent variables were assessed for census tracts including counts and density. The distribution of retailer

density and counts for census tracts were assessed prior to examining regression models. Counts and density for census tracts demonstrated Poisson distributions with a large majority being close to zero (heavily right skewed). Due to the non-normal distribution of counts, Goodness of fit (chi-square) tests performed using PROC GENMOD indicated that negative binomial distributions were a better fit. To control for potential confounding, census tracts models adjusted for tract population density *apriori*. SAS version 9.4 (SAS Institute Inc., Cary, NC, USA) was used for descriptive and regression analyses.

Justification of Analyses

The use of census tracts in this study provides an estimate of "neighborhood". Census tracts are built to have a population size between 1,200 and 8,000 people with most having an "optimum" size of 4,000. The defining border of a census tract is meant to cover a contiguous area following identifiable features, but it proportionally sized according to the population [184]. For the purposes of this study, retailer counts in "larger" census tracts (indicates low population density and thus have proportionally more land area), was greater than retailer counts for smaller census tracts (high density). The difference between population density and retailer counts provide to be problematic and thus it makes sense to examine retailer density. Within the literature, three main density types previously have been used when examining tobacco availability: retailers per 1000 population, retailers per land area, and retailers per 10km of roadway [137,149,185]. Maps of retailer densities for all three of these types of densities were examined in this study. Retailers per 10 kilometers of roadways was selected for two reasons: first, the use of roadway within a contiguous boundary correlated directly to the population size and the land area. The amount of roadway proportionally increased the higher the population density essentially controlling for the land area because tracts were the defining boundary.

Second, maps of the densities were created and the overall geospatial distribution of retailers per 1,000 population and per land area, appeared scattered with no overall pattern. Retailers per 10km of roadway however, demonstrated higher retailer density in more urban localities such as Richmond City and Colonial Heights, which was expected.

The distribution of the dependent variables (count, density, or at least 1 retailer) in this study were generally non-normal distributions. The two main continuous outcomes, count and density, could have been assessed as a linear regression model if the distributions were normally distributed, however they were skewed. Additionally, generalized linear models could have also been examined, however the Poisson distribution of the data indicated that a Poisson regression was better suited being that both the counts and density are non-negative outcomes and the data was heavily skewed to the right (majority of values toward zero). The equation for a Poisson regression model a log-linear model: $Log(Y) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 \dots\dots + \beta_i x_i$.

Within Poisson regression models, overdispersion is often an issue as these models require that the variance equal the mean. However, in many cases, the variance cannot equal the mean if the data is too heavily skewed indicating overdispersion. In cases where the variance exceeds the mean, overdispersion is present and a negative binomial model is used to overcome overdispersion by allowing for the standard errors of the mean to increase by adding an extra parameter to the model. To determine if overdispersion is present, Poisson regression models provide a dispersion parameter, *k*. If $k = 0$ then overdispersion is not present, but if the parameter is much higher than 0, overdispersion is present and a negative binomial model is needed in place of the Poisson model. Within PROC GENMOD, a Poisson model is first assessed prior to using a negative binomial model. The output provides a Pearson Chi-Square value, degrees of freedom, and the value divided by the degrees of freedom which is *k*. The equation for a negative

binomial regression model is: $Log(Y) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 \ldots\ldots + \beta_i x_i + \sigma\varepsilon_i$ where $\sigma\varepsilon_i$ accounts for extra variability (variance allowed to exceed the mean).

RESULTS

Descriptives

County-level

A total of 984 tobacco/e-cigarette retailers were found within the 13 counties and 4 principal cities of the Richmond, VA MSA (Table 4a.1 and Figure 4a.2). Retailer density within all counties was 0.19 per ten kilometers (km) of roadway (range 0.01-1.03). The densest localities (range: 0.55-1.03 retailers per 10km of roadway) consisted of the four principal cities in the Richmond MSA (Colonial Heights, Richmond, Hopewell, and Petersburg) and Henrico County, which surrounds the north side of the city of Richmond and has the highest area population. These localities also had the highest population density in the MSA and contained the majority of diverse or primarily non-white neighborhoods.

Census Tracts

On average, there were 3.42 retailers per census tract (range = 0.33-8.83) (Table 4a.1 and Figure 4a.3). For the SES quartile index variable, quartile 3 had the highest count of retailers with 276, with quartile 1 and 2 both having 263 retailers. Quartile 4, the highest SES quartile, however, contained only 170 retailers.

Higher Education Institutions

The average retailer density in census tracts containing campuses was 0.32 per 10-km of roadway, but ranged from 0.04 to 0.59 (Richmond MSA average 0.19) (Table 4a.2).

Neighborhood density counts (multi-ring buffers) around campuses averaged of 8.6 retailers (range 0-29) within a half-mile, 11.2 (range 1-23) between a half-mile and one mile, and 15.0 (range 0-46) between one-mile and two-miles. Total counts using multi-ring buffers showed 95 retailers within a half-mile, 124 between a half-mile and one-mile, and 165 between one-mile and two-miles (Figure 4a.3).

Using whole radius retailer proximity counts (the entire area up to the selected distance) for the 11 college campuses in the Richmond MSA, on average, campuses had 8.6 retailers within a half-mile (range 0-29), 19.9 within one-mile (range 3-41), and 34.9 within two-miles (range 3-75) using whole radius buffers. Total, there were 95 retailers with a half-mile, 219 with one-mile, and 384 with two-miles (Table 4a.2).

Bivariate analyses

Bivariate Analysis of Tobacco/E-cigarette Retailer Density and Counts with Census Tract Diversity

There was a significant difference when examining the average retailer density within census tracts between tract diversity (Table 4a.3). Diverse tracts on average had 0.25 retailers per 10km of roadway which was significantly higher than white (0.15) or non-white tracts (0.19). However, when examining retailer counts, there was a non-significant difference in the average number of retailers between white, non-white, and diverse tracts (range: 3.4-3.5).

Bivariate Analysis of Tobacco/E-cigarette Retailer Density and Counts with Socioeconomic Status

Census tracts in the lowest SES quartiles had significant differences for retailer density and counts and displayed contradicting results (Table 4a.3). Average retailer density in the

lowest census tract SES quartile (quartile 1) was significantly higher (0.26 retailers per 10 km of roadway) versus other quartiles (quartile two = 0.16, quartile three = 0.15, and quartile four = 0.16). However, average retailer counts were significantly lower in the highest SES quartile (quartile four = 2.4) versus other quartiles (quartile two = 3.7, quartile three = 3.7 and quartile four = 3.8).

Regression Analyses

Associations of Tobacco/E-cigarette Retailer Density and Counts with Socioeconomic Status Index

Generally, higher retailer density and counts within census tracts was associated significantly and moderately with lower socioeconomic status by census tract after controlling for tract population (Table 4a.4). Compared to those in census tracts of the highest SES quartile (Q4), quartiles the three lowest quartiles (Q1-Q3) were significantly associated with higher retailer counts at each level (aOR= 1.86 [95% CI 1.36-2.55]; aOR= 1.55 [95% CI 1.14-2.10]; aOR= 1.68 95% CI [1.24-2.28]). Conversely for density, compared to the highest SES quartile (Q4), only tracts in the lowest quartile (Q1) were significantly associated with higher retailer density (aOR= 1.56 [95% CI 1.08-2.25]).

Associations of Tobacco/E-cigarette Retailer Density and Counts with Tract Diversity Index

Only one association was found between tobacco/e-cigarette retailer density or count and census tract diversity. Higher census tract retailer density was associated significantly and moderately with living in a diverse census tracts compared to living in a primarily white census tract (aOR= 1.93 [95% CI 1.29-2.89]). None of the models for retailer count displayed statistically significant associations.

Associations of Tobacco/E-cigarette Retailer Density and Counts with Socioeconomic Status Index Creation Variables

To fully examine the relationship between retailer availability and socioeconomic status, each variable used to create the SES index was examined for associations with retailer density and counts while controlling for tract population. Higher retailer density was moderately and significantly associated with higher median income (aOR= 0.72 [95% CI 0.64-0.80]), higher household value (aOR= 0.87 95% CI [0.76-0.99]), higher percent unemployed (aOR= 1.93 [95% CI 1.29-2.89]), and higher percent in poverty (aOR= 1.30 [95% CI 1.19-1.41]). The protective associations seen between retailer density and median income and household value demonstrated that as both income and value increase, the retailer density decreases. Additionally, as the proportion of people in each tract who were unemployed or in poverty increased, retailer density and count with in each tract also increased. Conversely, higher retailer counts in tracts were moderately and significantly associated with lower median income, lower household value, higher percent unemployed, higher percent in poverty, and higher percent with less than high school educations (but not for percent college or higher).

DISCUSSION

The primary purpose of this study was to examine tobacco availability surrounding college campuses and the relationship between availability and socioeconomic status in Richmond, VA. Results demonstrated high retailer availability using both density and counts at distances less than two miles surrounding college campuses in the Richmond MSA. Furthermore, examination of the entire Richmond MSA demonstrated that retailer density and count were associated with low socioeconomic status census tracts, which is similar to previous research [154]. While this study did not examine the relationship between tobacco availability and use, previous

research has demonstrated that high retail density is associated with increased youth initiation and success of cessation attempts [137-139]. Retailer density rates found in this study are similar to studies examining density in relation to tobacco use in other localities [137,155].

Tobacco Availability and Neighborhood Environments Surrounding Higher Education Institutions

There are a large number of tobacco/e-cigarette retailer surrounding the 11 higher education institutions in Richmond. Due to the small number of college or university campuses in the Richmond MSA, this study could not test associations between surrounding tobacco availability and neighborhood environmental indicators surrounding college campuses. Nonetheless, on average, there were 8.6 retailers with a half-mile, 19.9 with one-mile, and 34.9 with two-miles surrounding college campuses in the Richmond MSA. Examination of various proximity distances proved to be important as retailer count appeared to increase expanding out from campuses.

Of the 11 campuses, there was an even split between four-year and community college campuses. Four-year institutions had a higher number of retailers and were located in tracts with higher retailer density on average. The retailer density with census tracts among the top four schools ranged from 0.58-0.59 retailers per 10km of roadway, which was much higher than the overall retailer density for the Richmond MSA (0.19 retailers per 10km of roadway). The campuses with the highest tract retailer density were all located in Richmond City, which had the second highest county-level density (0.88 per 10 km of roadway). The high overall density could be due to overall population density, but also influenced by the campuses in the Richmond MSA having a large proportion of their student population living on or near campus, whereas community colleges in the region tend to be commuter schools. Previous research has

demonstrated a relationship between colleges in cities having a higher density of retailers than those in rural areas, which was replicated in this study [186].

Examining multi-ring buffer proximity counts of retailers around campuses proved useful to understand the distribution of retailers into neighborhoods surrounding the campuses. Proximity counts of retailers around the college campuses can be considered a form of a density measure as retailer are counted within a radial buffer as specified distances. Retailer proximity counts surrounding college campuses increased at each distance from 95 retailers at a half-mile to 124 at one-mile, to 165 at two-miles. The increasing number of retailers moving away from campuses was somewhat of a surprising find as it was expected that the number of retailers would be highest closest to the campuses. However, the small number of retailers in close proximity could be a result of density or counts being biased due to campuses being treated as a single point, rather than as a large polygon and then applying buffers. The result could be an under-count of the true number of retailers if the buffers actually are cut short. Nonetheless, this study did include multiple distances to attempt to offset an under-counting issue and best describe the community or neighborhood area around the campuses.

Campuses with the highest retailer tract density did have a lower average density than Richmond City, indicating that there are other tracts in the city with even higher densities than near the campuses. While this study was unable to examine relationships of tobacco availability and characteristics of college campuses due to the small number of campuses within the Richmond MSA, the retailer counts and density surrounding the campuses in Richmond, demonstrated that college campuses do have a high number of retailers surrounding them than other areas of the MSA. The relationships between tobacco availability and socioeconomic status

of campus populations need to be assessed on a larger scale or in a region with a greater number of campuses.

Tobacco/E-cigarette Retailers in Richmond

Across the Richmond MSA, there was one retailer per 1,244 residents (range: 675-7,154) and an average of 3.4 retailers in each census tract. Retailer density (retailers per 10km roadway) was highest in the four principal cities (Colonial Heights, Richmond, Hopewell, and Petersburg) and Henrico County (range = 0.55-1.03) compared to other localities (cities and counties) (range= 0.01 – 0.31). Comparatively, retailer density in principal cities within the MSA were similar to other studies in other localities [146,154,177]. The average retailer density for the Richmond MSA was lower than compared to similar studies. For example, Cantrell et al. reported a retailer density of 0.38 retailers per 10km of roadways in the MSA's selected for their nationwide study. However, the MSA's of interest in that study had a much higher average population density [137] which could account for the difference.

For assessment of retailers in any locality, density is the preferred measure, particularly one that accounts for population and land area such as 10 kilometers of roadway for a few reasons. First, in this study, the average number of retailers or counts within census tracts provided biased results as rural localities with low retailer shop count and low overall density demonstrated high mean counts of retailers. Such a bias most likely indicates that these more rural localities have a few census tracts and a small number of them may have significant proportion of retailers. Second, examination of differences in retailer county by urbanicity or rurality within the study area could also have provided biased results due to a small number of localities and similar biased results of the average number of retailers. Lastly, regression analyses related to retailer counts displayed inconsistent associations particularly between

bivariate and multivariate associations, whereas associations for retailer density were consistent throughout.

Tobacco/E-cigarette Retailers and Socioeconomic Status within Census Tracts in Richmond

This study found moderate associations between tobacco availability and socioeconomic status within census tracts. The multivariate analysis demonstrated that there were significant associations between SES quartiles and retailer count and density, in addition to tract diversity and retailer density. Compared to SES quartile four (highest), all three lower quartiles demonstrated significant associations with retailer count, but when examining retailer density, only the lowest quartile had a significant association. The difference in the significant associations between SES quartiles when examining counts versus density supports the notion that retailer density is the superior measure, which is supported by other research [161]. Previous research has established that tobacco density is higher in areas where individuals tend to be less healthy and have higher proportions of non-white populations [146-149]. While this study did not examine health or behavior outcomes, the results found within the Richmond MSA census tracts confirm that counts and density are higher in low socioeconomic areas, particularly for lower income, lower home value, higher unemployment, and higher poverty.

Bivariate analyses examining average retailer count and average retailer density for SES and diversity within tracts also demonstrated that retailer density is a superior and more consistent measure. For retailer counts, census tracts with that were the highest SES quartile had a significantly lower average number of retailer compared to those in the lowest three quartiles. Comparatively, the significance reversed when examining retailer density as those in the lowest SES quartile had a significantly higher retailer density compared to other quartiles. This result

was what was hypothesized originally and because density accounts for land and population by calculating the number of retailers per 10 km of roadway, is the less biased measures compared to counts. Significant differences were expected to be found between the highest and lowest SES census tracts, however the average number of retailers (counts) for census tracts in the middle quartiles (Q2 and Q3) and the lowest quartile (Q1) were not different. The significant differences reversed when examining density, as the middle quartiles (two and three) were not different and were similar to the highest quartile (four). The observed results by SES level were all very similar to the average retailer count and density in the entire Richmond MSA (3.4 for counts and 0.19 for density). There were no differences in the average number of retailers among census tract racial groups, however there were significantly differences when examining density. It was expected that census tracts that were predominantly non-white or diverse, would have a higher average retailer counts, which held true for diverse tracts having a significantly higher retailer density. Average density of retailers in non-white tracts were not significantly different from white tracts.

Future Work and Notes

Future work examining tobacco retail outlets in comparing different localities could employ a similar data collection strategy as this study, allowing for an examination of the relationship between tobacco availability, tobacco use, and socioeconomic status, while controlling for sociocultural aspects and local or state policy. The results of this study provide similar evidence to other research addressing community environment such as community health indicators, availability of healthy food, and the influence an individual's area has on health[148,180,187,188]. Thus, the availability of tobacco products could be a key community health indicator for individuals living within census tracts containing high retail density in the

Richmond MSA. Future public health research and action may find it useful to monitor tobacco retail density and counts as a community health indicator and thus a potential point of regulation. From a policy perspective, tobacco retail counts and density are potentially valuable information for policy and planning purposes. Localities that do not monitor retailers miss out on information that directly impacts community environments and could serve as a proxy health measure.

This study indicates that retailers such as convenience stores or gas stations may be more important when examining retailer availability, particularly in relation to youth and young adult use and for policy and regulatory purposes. Much of the attention about e-cigarettes has been for vape shops, however these shops were a small proportion of retailers in Richmond using this study's data collection technique. Collecting availability data from e-cigarette brand websites allowed for examination of the frequency of brands in localities. Overall, Blu e-cigarettes were in a total of 89% of locations collected in this study. However, among other brands the next highest proportion of brand availability was only 19% (NJOY and v2). Interestingly, the use of Yelp and Google only produced approximately 5% (n=47) of the retailers collected for this study and commonly were "vape shops" or retailers that sell specialty e-cigarettes products such as "Mods" (e-cigarettes that have been modified or changed) and e-liquids.

Study Limitations

One major limitation of this study influenced the results with respect to higher education institutions. Attempting to examine tobacco/e-cigarette availability in relation to higher education institutions in the Richmond MSA proved to be highly problematic due to the small number of higher education institutions. The Richmond MSA has only 11 higher education institutions that make up both public and private, in addition to two- and four-year institutions. To overcome the sample size issue, the addition of examining tobacco/e-cigarette retailers within

census tracts within the Richmond MSA proved informative and provided important results. Nonetheless, this study attempted to overcome the issue of small numbers in a few ways. First, census tracts were examined that directly surrounded campus locations to in order to directly compare with each campus census tract location. Examining census tracts surrounding tracts containing a campus proved to be biased as campuses in more rural areas were located in very large census tracts and often had surround census tracts that were also rural and thus large. The result demonstrated that there were no significant differences between tracts with campuses and tracts without. Next, consideration was given to attempting to examine campuses across the entire state of Virginia, however doing so would also prove to be problematic as Virginia has just 34 two- or four- year institutions which would still have the issue of small numbers. Lastly, in order to have a large enough sample size of campuses, campus locations across multiple states would have to be examined. The use of multiple states would provide biased results as states have different socioecological factors that influence use, including different use rates, different cultural expectations, and different policies and regulations. Thus, as a secondary part to this study meant to overcome the methodological issues presented above and to provide an additional geospatial view of tobacco availability in Richmond, primary and secondary K-12 public schools were examined. This secondary study can be found in Chapter 2b.

This study also had other important limitations. First, this study collected data from e-cigarette brand websites to be used as a proxy for tobacco locations in the Richmond, VA MSA. The assumption was made that any location carrying these brands, would also carry tobacco products as many retailers have contracts with tobacco companies. The possibility also exists that the data obtained are an extremely conservative estimate of the actual number of locations within the MSA due to using e-cigarette retailers as the proxy measure. Second, only six major brands

were selected for data collection. These brands however, appear to be the most popular cig-a-like brands or owned by major tobacco industry corporations. Third, the data was collected over a two-week period once. E-cigarettes have drastically grown in popularity overtime, however major brands, such as those used in this study are most likely continue to expand their availability. Fourth, this study did not validate that products were actually carried in store, but did validate that locations actually existed using Google Street view for half of the sample. Fifth, recent deeming policy by the Food and Drug Administration could reshape e-cigarette availability by consolidating the overall e-cigarette market, which could limit the value of future data collection methods used in this study. Sixth, the geographic units of observation in this study were considered independent rather than being spatially dependent as they could have been. Lastly, while the Richmond, VA MSA is a fairly representative city, generalization of this study's results may not be representative for other cities or MSAs across the US.

Implications and Conclusions

There are a few important implications from this study. First, tobacco and e-cigarettes are widely available in neighborhoods surrounding college campuses in Richmond. Census tracts containing college campuses had a higher retailer density on average than the overall average number of retailers within census tracts of the Richmond MSA, in addition to tracts without campuses. While this study did not assess tobacco use in relation to availability, it is well established that higher retailer density influences youth and young adult smoking rates [7,137,138,155]. Therefore, local policy addressing retailer density could have effects on college student tobacco use in the Richmond MSA.

Second, retailer density in this study was higher in lower socioeconomic census tracts within the Richmond MSA and similar disparities in use between socioeconomic status and

tobacco use in the Richmond area could also exist. Previous work has examining tobacco availability and tobacco use often examine socioeconomic or sociodemographic factors as confounders or interactions within the relationship. Additionally, few studies have examined the association between availability and socioeconomic status [149,189]. Previous work has shown that that reducing tobacco density surrounding schools in low socioeconomic areas can reduce socioeconomic and racial disparities in use [190]. From a policy perspective, reducing or controlling the number of retailers in low socioeconomic areas could potentially have an effect on overall use rates among youth populations that are highly vulnerable.

Lastly, from a methodological standpoint, the use of e-cigarette brand websites as a data collection tool appeared to be a good proxy for examining overall tobacco availability in the Richmond MSA as the density of retailers in Richmond is similar to that of other studies. However, the results of this study may still be under representative of all tobacco/e-cigarette retailers in the locality. Nonetheless, these methods could be applied to other localities that do not employ retailer tracking databases or those wishing to determine where e-cigarettes are being sold in their communities.

Table 4a.1. Tobacco/E-cigarette Retailers and Characteristics of the Richmond, Virginia Metropolitan Statistical Area

	Tobacco/E-cigarette Retailers				Population Density[b]		SES Index Quartile Tract Count[c]				Race Composition Tract Count[d]		
County/City	**Retail shops**	**Density[a]**	**Residents per retailer**	**Mean retailers per tract**	**Census Tracts**	**Residents per sq. mile**	**SES 1**	**SES 2**	**SES 3**	**SES 4**	**White**	**Non-White**	**Diverse**
Colonial Heights City	26	1.03	675	5.20	5	2,358	1	2	2	0	5	0	0
Richmond City	194	0.88	1073	2.98	65	3,643	28	10	9	18	23	12	30
Hopewell City	24	0.70	932	4.00	6	2,159	4	2	0	0	2	2	2
Henrico County	241	0.59	1285	3.75	61	1,378	9	17	13	22	38	9	14
Petersburg City	38	0.55	854	3.45	11	1,426	8	2	1	0	0	0	11
Chesterfield County	209	0.31	1552	2.94	71	785	9	18	20	24	53	12	6
Hanover County	84	0.14	1199	3.65	23	218	0	2	15	6	23	0	0
New Kent County	23	0.11	834	7.67	3	95	0	0	3	0	3	0	0
Powhatan County	20	0.09	1410	4.00	5	109	0	1	4	0	4	0	1
Caroline County	33	0.07	881	4.71	7	56	2	5	0	0	6	1	0
Goochland County	15	0.06	1442	3.00	5	81	1	0	2	2	4	0	1
Prince George County	18	0.06	2044	2.57	7	141	1	4	2	0	4	3	0
King William County	12	0.05	1337	3.00	4	59	0	3	1	0	3	1	0
Dinwiddie County	23	0.04	1217	8.83	6	55	3	3	0	0	4	2	0
Sussex County	16	0.04	648	4.00	4	24	4	0	0	0	1	2	1
Amelia County	7	0.02	1823	3.50	2	36	0	2	0	0	2	0	0
Charles City County	1	0.01	7154	0.33	3	38	2	1	0	0	0	2	1
Total or Average	**984**	**0.19**	**1244**	**3.42**	**288**	**276**	**72**	**72**	**72**	**72**	**175**	**46**	**67**

Notes:

a. Density = Retailers per 10km of roadway in census tract

b. 2014 American Community Survey

c. Tract SES index based on factor analysis of 6 variables including: % unemployed, % below poverty threshold, % less than high school education, % college education or higher, median tract household value, household median income. Factor analysis used to create quartile scores

d. Categories may not add up to 100% because reporting did not capture categories of multiple race/ethnicities

Table 4a.2. Richmond MSA Higher Education Tobacco/E-cigarette Retailer Counts and Characteristics

Institution Name	Institution Type	Institution Population[a]	Retailer count[b]: < 0.5 mile	Retailer count[b]: < 1-mile	Retailer count[b]: < 2-miles	Retailer count[c]: > 0.5 and ≤ 1 mile	Retailer count[c]: > 1 and ≤ 2-miles	Tract Retailer Density[d]	School Diversity	Tract Diversity	Tract SES Quartile
Virginia Commonwealth University-Monroe Park	4-year public	29.242	29	41	68	12	27	0.59	Diverse	Diverse	2
Virginia Commonwealth University-MCV Campus	4-year public	2,000	15	37	67	22	30	0.58	Diverse	Diverse	2
Virginia Union University	4-year public	1,906	13	35	64	22	29	0.58	Non-White	Non-White	2
Randolph-Macon College	4-year private	1,420	10	19	19	9	0	0.30	White	White	2
John Tyler Community College-Chester	Community College	5,072	10	15	16	5	1	0.28	White	White	3
Virginia State University	4-year public	4,696	7	14	30	7	16	0.17	Non-White	Non-White	1
J Sargeant Reynolds Community College - Downtown Campus	Community College	12,454	6	29	75	23	46	0.58	Diverse	Diverse	2
University of Richmond	4-year private	4,177	3	8	8	5	0	0.20	Diverse	White	4
J Sargeant Reynolds Community College - Western Campus	Community College	-	2	3	3	1	0	0.04	Diverse	White	3
J Sargeant Reynolds Community College - Parham Road Campus	Community College	-	0	13	25	13	12	0.18	Diverse	White	3
John Tyler Community College-Midlothian	Community College	5,073	0	5	9	5	4	0.06	White	White	4
Total or Average	**-**	**64,485**	**95**	**219**	**384**	**124**	**165**	**0.32**	**-**	**-**	**-**

Notes:

a. For J. Sargeant Reynold campuses, student population is reported for all three combined
b. Whole Radius buffer = Not mutually exclusive
c. Multi-Ring buffer = Mutually exclusive
d. Density = retailers per 10km of roadway in census tract

Table 4a.3. Bonferroni Pairwise Comparisons of Average Number of Retailers for Tracts in Richmond, VA MSA

	Count[c]	Density[d]
Tract SES Quartiles[a]		
1 (lowest)	3.7	**0.26****
2	3.7	0.16
3	3.8	0.15
4 (highest)	**2.4****	0.16
Tract Diversity[b]		
White	3.5	0.15
Non-white	3.4	0.19
Diverse	3.5	**0.26****

Notes:

a. SES index: higher quartile, better SES score (i.e. higher SES)
b. Diversity: White >60%, Non-white >60%, Diverse <60% both
c. Count = Whole radius buffer
d. Density = retailers per 10km of roadway in census tract

Table 4a.4. Multivariate Analysis of Tobacco/E-cigarette Retailers and Census Tracts in Richmond, VA MSA

		Count			Density[a]		
		aOR	95% CI	p-value	aOR	95% CI	p-value
Tract SES Quartiles[c]	1	**1.86**	**1.36-2.55**	**<0.01**	**1.56**	**1.08-2.25**	**<0.01**
	2	**1.55**	**1.14-2.10**	**0.01**	0.98	0.65-1.48	0.93
	3	**1.68**	**1.24-2.28**	**<0.01**	0.93	0.61-1.40	0.71
	4 (ref)	-	-	-	-	-	-
Diversity[g]	White (ref)	-	-	-	-	-	-
	Black	1.11	0.82-1.50	0.50	1.26	0.85-1.85	0.25
	Diverse	1.13	0.87-1.47	0.36	**1.68**	**1.23-2.28**	**<0.01**
SES variables[cdef]	% Unemployed	**1.47**	**1.01-2.16**	**0.05**	**1.93**	**1.29-2.89**	**<0.01**
	% In poverty	**1.18**	**1.06-1.30**	**<0.01**	**1.30**	**1.19-1.41**	**<0.01**
	% Household value	**0.86**	**0.78-0.95**	**<0.01**	**0.87**	**0.76-0.99**	**0.03**
	% Income[d]	**0.80**	**0.74-0.88**	**<0.01**	**0.72**	**0.64-0.80**	**<0.01**
	% Less than HS grad	**1.15**	**1.02-1.29**	**0.02**	1.13	0.99-1.28	0.06
	% College or higher	0.95	0.90-1.01	0.08	1.04	0.97-1.11	0.28

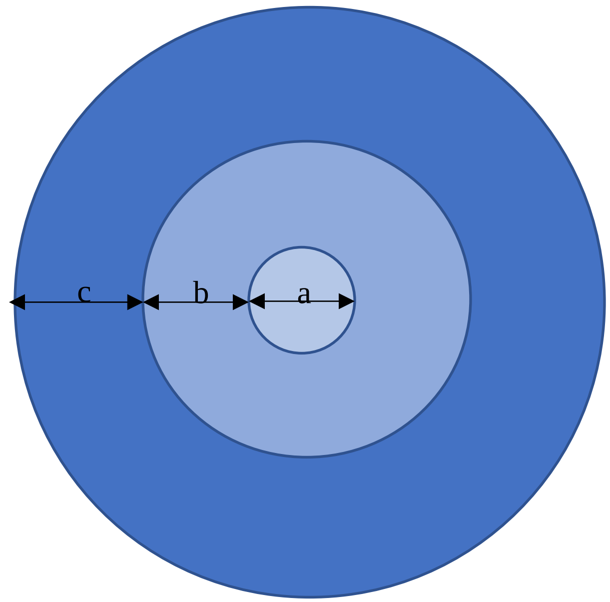
Notes:

a. Density = retailers per 10 km of roadway within census tracts
b. All models control for Tract Population
c. SES = Socioeconomic Status, SES index: higher quartile, better SES score (i.e. higher SES)
d. Range of variable 0-100%
e. Percent of highest tract median value
f. Continuous variables presented in deciles (10% or 10-unit increase interpretation)
g. Diversity: White >60%, Non-white >60%, Diverse <60% both

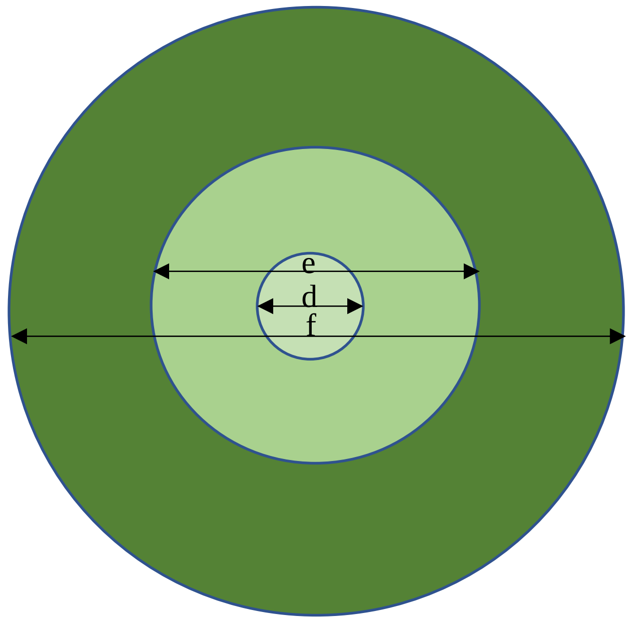
Figure 4a.1. Buffer Types and Distances for Measuring Retailer Count

Buffer types used in this study surrounding college campuses in the Richmond for spatially determining retailer counts. Use of these buffers in addition to the retailer counts is a form of a density measure as the buffers are built on distances from each campus.

Multi-ring (concentric) Buffer



Whole Radius Buffer



a. ≤ 0.5 mile
b. > 0.5 mile, but ≤ 1.0 mile
c. > 1 mile, but ≤ 2.0 miles

d. ≤ 0.5 mile
e. ≤ 1.0 mile
f. ≤ 2.0 miles

Figure 4a.2. Retailer Locations within Counties of the Richmond, VA MSA

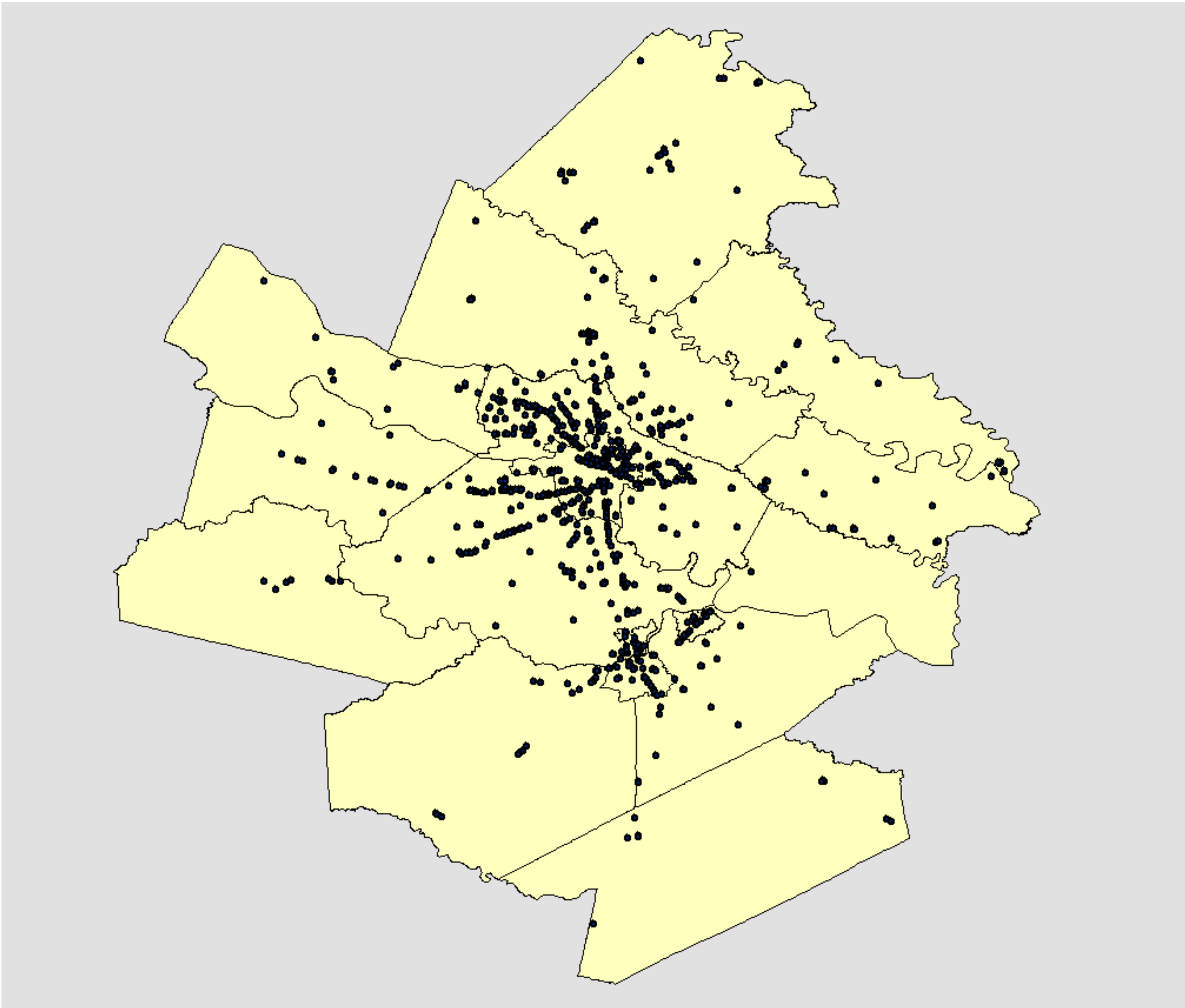


Figure 4a.3. Retailer Locations within Census Tracts of the Richmond, VA MSA

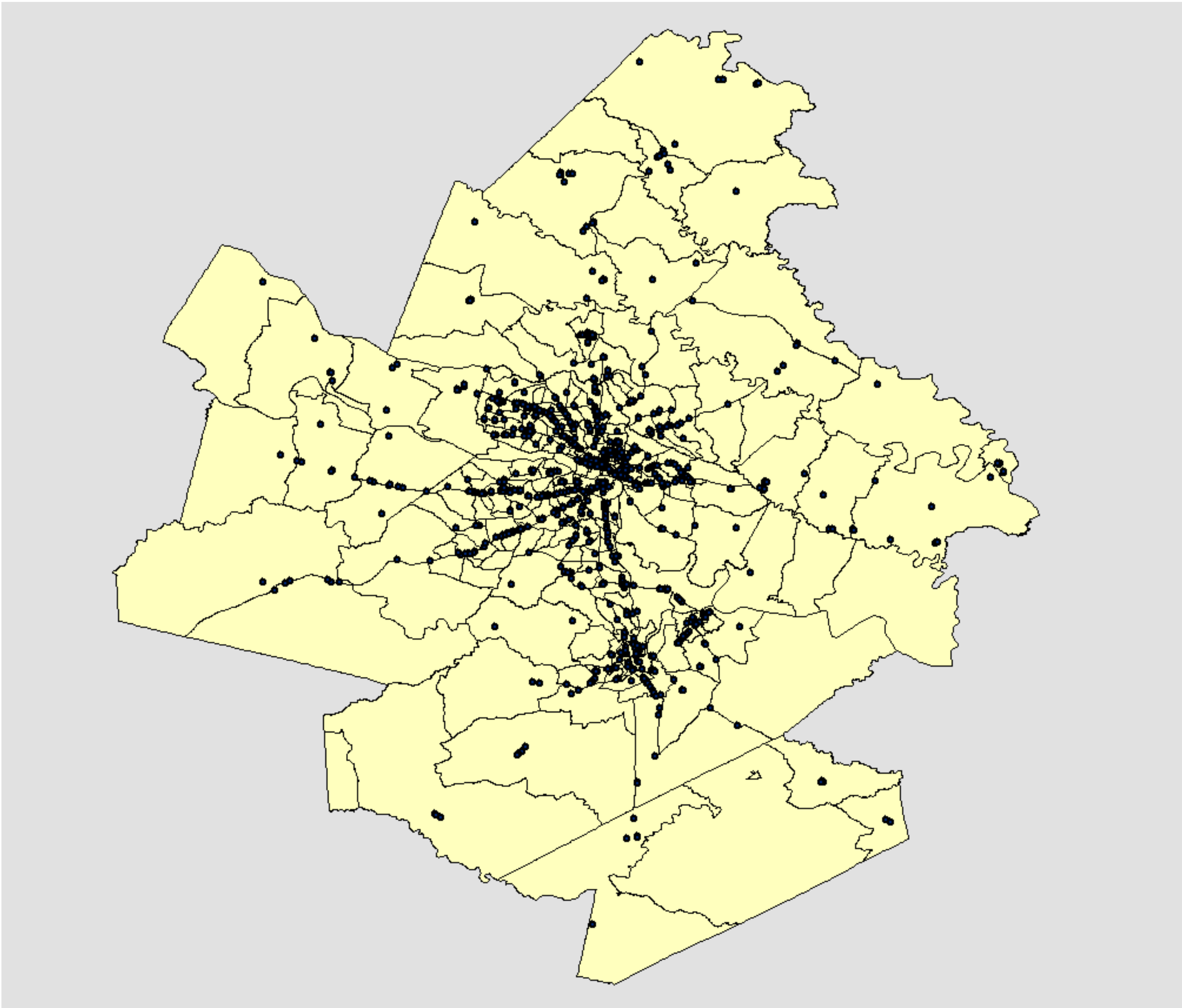
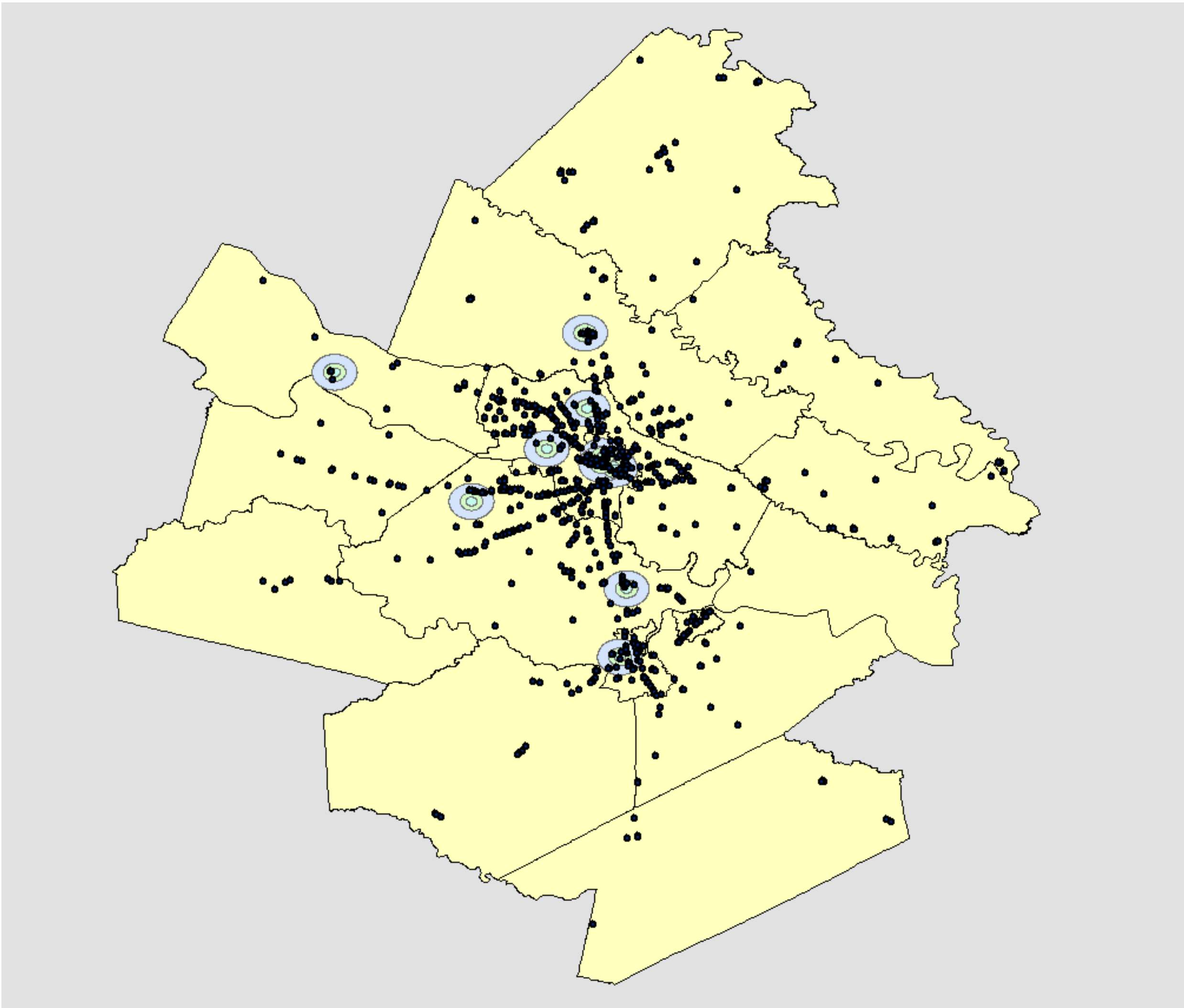


Figure 4a.4. Retailer Locations and Buffers Around Higher Education Institutions within Counties of the Richmond, MSA



CHAPTER 4b: Tobacco/ E-cigarette Availability around K-12 Public Schools and in Neighborhoods of Richmond, VA

ABSTRACT

Background: Restricting tobacco retailer density or proximity distance to schools can reduce youth smoking. However, there is a lack of information on where tobacco and e-cigarettes products are sold within communities, particularly around K-12 schools. Retailer data locations from e-cigarette brand websites could be used to analyze geospatial locations of tobacco/ e-cigarette retailers.

Objective: Examine spatial tobacco/e-cigarette retailer locations in close proximity to schools testing the relationship between the availability of tobacco products and school/neighborhood-based socioeconomic status (SES).

Methods: Location addresses were collected for six popular e-cigarette brands within the Richmond, Virginia Metropolitan Statistical Area (RVMSA). Tobacco/e-cigarette retailer location data were merged with 2013 Elementary and Secondary System public school data and 2014 American Community Survey data. The primary outcome was retailer counts within a half-mile, 1-mile and 2-miles (Euclidean radii) of public schools. An additional outcome of retailer counts and density within census tracts was also examined. Associations between the number of retailers and school/neighborhood- level SES measures were tested using Poisson regression including: quartiles of percent receiving free/reduced price lunch, racial/ethnic diversity of the student population, racial/ethnic diversity of the neighborhood for which school is located, and tract-level SES index quartiles.

Results: A total of 984 tobacco/e-cigarette retailers were found in the RVMSA, with an overall density of 0.19 retailers per 10km of roadway (county-level range: 0.01-1.03). Of the 260 schools identified, 45% had a retailer within a half-mile, 76% within 1 mile, and 92% within 2

miles. After adjusting for student enrollment, higher retailer counts within a half-mile of public schools was associated with schools having greater numbers of students receiving free/reduced price lunch (AOR: 2.37 (95% CI 1.36-4.15)), a diverse student population (AOR: 2.14 [95% CI 1.41-3.25]), and schools located within the lowest neighborhood SES quartile (AOR: 1.93 [95% CI 1.09-3.41]). Additional moderate and significant associations were found at the other distances.

Conclusions: The detected association between schools located in close proximity to tobacco/e-cigarette retailers with lower school- and neighborhood-level SES in the RVMSA is similar to prior availability studies. Restricting the number of retailers within close distance to schools could lower youth access to tobacco within the RVMSA. Therefore, low SES schools could be potential target for policies restricting tobacco sales.

INTRODUCTION

In the previous chapter of this dissertation (2a), tobacco/e-cigarette availability and retailers were examined in relation to higher education institutions and within neighborhood communities (census tracts) of the Richmond, Virginia Metropolitan Statistical Area (MSA). The results of that study demonstrated that tobacco/e-cigarette retail density is higher in lower socioeconomic status (SES) and in diverse census tracts, in addition to being highly prevalent around the eleven higher education institutions in the Richmond MSA. That study however was limited by the available statistical power of having few college campuses. To overcome sample size limitation and provide a more complete view of tobacco availability in Richmond, this sub-chapter will examine tobacco/e-cigarette availability surrounding schools by using similar density measures (proximity counts) as those used for higher education institutions. The use of K-12 schools could serve as a proxy measure for describing the relationship between tobacco/e-cigarette availability and neighborhoods surrounding higher education institutions. Additionally, this study will repeat descriptive methods, analyses, and some results for tobacco/e-cigarette availability and neighborhoods within the Richmond MSA, however it will also provide additional descriptive, bivariate, and multivariate regression analyses for availability surrounding K-12 schools. These results will provide a comprehensive interpretation of the relationship between availability, schools, and neighborhoods.

Background

Tobacco/e-cigarette retailers, including grocery stores, gas stations, and markets selling tobacco products account for the majority of sales of tobacco products [141] and frequently are visited by youth and young adult populations. The retail location is known as the point-of-sale and often contains extensive marketing and direct in-store advertising for tobacco products and

brands [191,192]. Studies examining youth behaviors have reported that frequency of visiting tobacco-selling retailers increases the likelihood of ever trying cigarettes or smoking initiation [145,162]. Spatial patterns of tobacco use exist in small areas and communities [160] and is related to the density or overall number of retailers within the locality [159]. Youth populations are often thought to be the most vulnerable to tobacco availability, particularly in regard to initiation [150,151]. Retailer density is a function of tobacco availability within communities or neighborhoods and is associated directly with youth smoking rates [155]. Schools in particular are of interest as the density and proximity of retail outlets influences youth smoking behaviors[138,162]. For youth populations, policy restrictions in communities on where products can be sold have the potential to impact use behaviors [138,157,158]. For example, a restriction on sales using a "minimum allowable distance from schools" policy could reduce substantially the number and density of tobacco/e-cigarette retailers within a community [144]. Such a restriction could influence youth smoking behaviors by denormalizing the behavior and limiting youth access to products. However, while research on availability has shown a relationship with youth behaviors, many localities and even states do not know where products actually are being sold in relation to schools, particularly for youth attending low SES schools.

While retail outlets are commonplace within communities, some localities and states do not monitor or license tobacco/e-cigarette retailers. States that do not monitor retailers present a challenge as available spatial and geographic data on retailers does not exist. For example, in Virginia, tobacco licensure is conducted at the distributor level, a step above the retail outlet within the supply chain [166], resulting in a lack of knowledge for policymakers on where products are sold. To overcome the lack of knowledge, a recent study by Cantrell et al. (2016) took a different approach to retailer data collection at the national level by creating a list of "likely"

tobacco retailers using the 2012 North American Industry Classification Systems (www.naics.com) of all supermarkets, grocery stores, convenience stores, alcohol retailers, drug stores/pharmacies, tobacco retailers, and gas stations with convenience stores [137]. The approach described by Cantrell et al. attempts to create an accurate database of locations; however, it lacks the precision needed for informed policymaking, particularly at the state or local level where most regulation occurs. Product validation studies are another form of research that examines tobacco availability. Product validation studies are observational studies that assess which products are carried in retail stores. These studies provide spatially precise and accurate data, however are often limited in their overall study area and are time and resource intensive [39,165]. Examining availability in neighborhoods in relation to SES, including SES of K-12 schools could provide information on spatial differences in availability in the Richmond localities as data on these schools is readily available and can easily be spatially joined using census tracts.

Study Purpose

The recent rise in popularity of electronic cigarettes (e-cigarettes) has created a new dimension to the tobacco market and an opportunity to assess where e-cigarettes are being sold. The availability of obtainable data from e-cigarette brand websites could provide information to policymakers as the available authority to address retail density lies within local governments, where direct regulation, licensing, or zoning policies can be used to as a reduction tool [144]. A recent study by Wagoner et al. found that e-cigarettes are available widely in tobacco shops, pharmacies, convenience stores, and gas stations [39]. In theory, if a location carries e-cigarette products, they also sell other tobacco-based products. Popular brands such as Blu or NJOY e-cigarettes, list locations sold directly on their websites, which can be a primary source for obtaining information about where they are sold to consumers.

The purpose of this study is two-fold: 1) determine density and counts of tobacco/e-cigarette retailer shops in census tract and county-equivalent boundaries of the Richmond, Virginia MSA; and 2) assess the relationship between tobacco/e-cigarette retailers in the Richmond Metropolitan Statistical Area (MSA) and SES, in addition to neighborhood counts and proximity to schools. Tobacco/e-cigarette retail density is hypothesized to be higher in lower SES areas, around K-12 schools (census tract neighborhood), and will be associated with lower SES within census tracts and lower SES K-12 schools.

METHODS

Study Area

The study area for this project is the Richmond, VA MSA. The Richmond MSA is located in the eastern-central Virginia comprising 13 counties and 4 equivalent principal cities (Table 1) [170]. The total land area is approximately 4,600 square miles with a population of 1.2 million people [170]. Based on population, the Richmond MSA is 45th largest according to the US Census Bureau[171] and the locality overall is highly diverse.

Data Collection

Locations of tobacco/e-cigarette retailers were collected directly from six websites of popular e-cigarette brands and from two additional websites by name, street address, city, and zip code. E-cigarette brand websites were used as a proxy for where tobacco products are sold as Virginia does not license retailers and therefore does not have a database of retailers. Brands were selected based on the results in previous studies [172,173], those shown to be popular among young people [174], those that had provided map-based website location finders. Brands included: Blu, NJOY, V2, Green Smoke, VUSE, and MarkTen. Two additional websites including

Yelp.com and Google.com were used to capture non-traditional tobacco/e-cigarette retailers such as vape shops. Embedded location finders on the brand websites provide addresses within a website-specified distance from an entered zip code. During two weeks in early January 2016 the data were web-scraped (copied and pasted) from e-cigarette brand websites by entering zip codes in the Richmond MSA, aggregated, and cleaned in Microsoft Excel spreadsheets to remove duplicate locations.

Census tract and county shapefiles for the Richmond, MSA were obtained from Census TIGER/Line [175]. There is a total of 288 census tracts in the Richmond, VA MSA. Census-tract level data were obtained from the 2014 American Community Survey for SES and race variables. K-12 School data was obtained from the National Center for Education Statistics (NCES) Elementary and Secondary Information System (ELSI). The Virginia Commonwealth University Institutional Review Board deemed the current study exempt as it utilizes non-human secondary data.

Geocoding

Addresses for retailers were geocoded using ArcGIS 10.4 [176]. Only geocoded address points or street addresses were accepted as viable points. Based on the geocoded points, a total of 1,365 retailers were collected using the zip codes. Using ArcGIS, all 1,365 points were spatially joined and only those within the Richmond MSA were kept resulting in 984 distinct retailers. Google Street View was then used to validate 50% of locations to ensure precision and accuracy of geocoding. Point shapefiles were created for retailer outlets using the North American Datum of 1983 (NAD 83) State Plane (2011) Virginia South projection.

Measures

Retailers

For each retailer, name, address, city, state, and zip code were collected. Additional variables were added for brands collected. To estimate the distribution of retailers across the Richmond MSA, three outcomes were evaluated: tract count, tract density, and school proximity count. Retailer tract count refers to the number of retailers that Fall within a census tract. A density measure of retailer count within each census tract was calculated. Density was calculated as the number of retailers per ten kilometers of roadway using a shapefile obtained with county and census tract shapes from TIGER/line. The retailers per 10km of roadway density measure accounts for both land area and population density and has previously been used [154,177]. School proximity count is being assessed using three distances (half-, one-, and two-miles) and two types of buffers (multi-ring neighborhood and entire neighborhood) resulting in five distinct proximity measures related to schools and explained within the *Proximity Measures and Buffers Around Educational Institutions* section. The use of proximity counts within buffers surrounding school each can also be considered a density measure rather than a count as the counts are within the specified distances.

County-Equivalents and Census Tracts

Using data from the 2014 American Community Survey (ACS), data collected for county-equivalents and census tracts included demographic information such as population total, racial composition, and socioeconomic-based variables. SES status variables were selected based on previous literature for creation of an SES index using principal components of a factor analysis at the census tract-level [178,179]. The variables selected were: percent unemployed, percent

below poverty threshold, percent less than high school education, percent college education or higher, median household value, and median household income. Variables were standardized and a factor analysis was used to create factor scores that were then divided into quartiles. Lastly, a race diversity index was created based on previous work [180,181] and was recoded as a three-level variable based on the predominate race within a census tract. Race was recoded as a three-level variable because within census tract data, racial groups are given as proportions in separate variables. The race diversity index provided the ability to analyze racial groups as levels of a single variable. The race diversity index was assessed by tracts containing >60% White indicating the tract is majority White, >60% Non-white which indicates that the tract is majority non-White, or less than 60% of both indicating the tract is racially diverse.

Public and Private Schools

Public and private school data was obtained separately due to a lack of available variables for private schools. A total of 327 public schools and 75 private schools defined by the National Center for Education Statistics exist in the Richmond MSA. However, the resulting list also contains schools that were not a traditional primary, middle, secondary, or combined school. Schools not meeting one of these criteria were excluded, resulting in 268 public schools and 74 private schools. Demographic variables included: school population, population by grade, and racial composition, and percent of students received free or reduced price lunch (only for public schools). Additionally, the previously determined census tract SES index groups were spatially joined to each school to provide information on the school “neighborhood”. School institutional variables included address information, latitude/longitude, and school type/level. Race was assessed using the race diversity index described above where a school was primarily white (>60%), primarily non-white (>60%), or racially diverse (neither >60% for white or non-white).

Proximity Measures and Buffers around Educational Institutions

To measure proximity counts, Euclidean radial buffers were created from each school centroid. Euclidean radial buffers are user determined, straight-line distance measured from a center point (school) where proximity counts are then determined for all points (retailers) Falling within the radial buffer. For this study, three buffer distances of half-, one-, and two-miles were created. Based on previous work, the half-mile buffer appears to be the most commonly used distance concerning retailers as it would be about a ten-minute walk [94,182,183]. One- and two mile buffers were also selected to be used for purposes of describing what an entire neighborhood may look like surrounding schools. Two types of buffers were applied at each distance, whole radius and multi-ring (concentric) buffers (Figure 1). Whole radius buffers cover the entire distance of each buffer (i.e. 0-0.5 mile, 0-1 mile, and 0-2 miles). The multi-ring or concentric buffers cover area excluding the smaller buffers (i.e. 0-0.5 mile, >0.5-1 mile, >1-2 miles). The difference between these types of buffers is that retailer counts within neighborhoods using multi-ring buffers would be mutually exclusive between buffer sizes, whereas for whole radius buffers, results would not be mutually exclusive and retailers could be counted up to three times when examining larger buffers. School-based buffers also may cross-over other school buffers if they are within two miles of each other, resulting in some retailers being counted multiple times. As an example, if a retailer was found to be within a half-mile of a school, that same retailer would then be counted two more times in the one- and two-mile whole radius buffers. If the same retailer was within a half-mile of three schools, the retailer would be counted up to three times for multi-ring buffers and up to nine times for whole radius buffers for all three distances. The created buffers were spatially joined with the retailer dataset to provide a count of the number of retailers within each buffer. None of the school-based buffers overlapped outside of

the study area, but some did cross over county or census tract boundaries. To avoid confusion with the buffers, the multi-ring buffers will be referred to as half-mile neighborhood (<0.5 mile), one-mile neighborhood (>0.5- 1 mile), and two-mile neighborhood (>1-2 mile) whereas the whole radius buffers will be referred to as half-, one-, and two-mile buffers.

Analysis

Descriptive statistics

Descriptive statistics were assessed at county and census tract levels for the entire Richmond MSA including retailer count, retailer density in tracts (retailers per ten-kilometers of roadway), population per retailer, mean number of retailers per census tract, and population demographics (population density, SES index, and race). As a result of collecting retailer location from brand websites, brand counts by county were also determined.

Descriptive statistics for public and private schools were examined including retailer counts in neighborhoods surrounding each school using both buffer types, whole and multi-ring buffers, at half-, one-, and two-miles. School locations were spatially joined (merged) with census tract information to obtain a tract-level SES index value and tract retailer density.

Bivariate and Multivariate Analyses

Bivariate analysis examining retailer counts and density was initially conducted for census tracts and public and private schools separately. During these comparisons, it was determined that private schools were unable to be assessed due to small numbers (n=74) as all relationships were non-significant. For census tracts, the average number of retailers by tract SES index quartiles and tract racial diversity index were examined using Bonferroni Pairwise Comparisons to control for Type 1 error. Type 1 error can occur when comparing differences

between more than two means within a single variable (e.g. SES index is split into quartiles, thus has a mean value for each quartile) producing statistically significant differences, when they do not exist. ANOVA was used to perform the bivariate analysis via the PROC ANOVA procedure in SAS 9.4. PROC ANOVA displays average means and determines if there is a statistically significant difference between levels of each variables. For public schools, Bonferroni Pairwise Comparison using PROC ANOVA were also used to assess SES index quartiles, tract racial diversity index, school racial diversity index, school level, and quartiles of those receiving free/reduced price lunch.

Multivariate analyses were conducted for census tracts and public schools. Four separate regression analyses were conducted two for census tracts (counts and density) and two for schools (proximity counts and at least 1 retailer within each distance). The regression analyses examined the relationship between availability (counts and density) and SES and race. Two dependent variables were assessed for census tracts including counts and density and two for public schools, including proximity counts. For census tracts, retailer count and density were examined with SES and for school retailer counts within half-, one-, and two-mile proximity Euclidean distances and whether or not there was at least 1 retailer within half, one-, and two-mile proximity from the school (coded as 0/1).

The distribution of retailer density and counts for census tracts and counts within half-, one-, and two-mile proximity to schools were assessed prior to examining regression models. Counts for schools and census tracts and density for census tracts all demonstrated Poisson distributions with a large majority of counts and densities being close to zero (heavily right skewed). Due to the non-normal distribution of counts, Goodness of fit (chi-square) tests performed using PROC GENMOD indicated that negative binomial distributions were a better

fit. To assess the association between having at least one retailer within half-, one-, or two-mile proximity to schools, logistic regression was used. To control for confounding, two variables included in each data set were selected *a priori*. School models assessing count or at least one retailer within half-, one-, and two-miles adjusted for student enrollment, while for census tracts models adjusted for tract population density. SAS version 9.4 (SAS Institute Inc., Cary, NC, USA) was used for descriptive and regression analyses.

RESULTS

Descriptives

County-level

A total of 984 tobacco/e-cigarette retailers were found within the 13 counties and 4 principal cities of the Richmond, VA MSA (Table 4b.1 and Figure 4b.2). Retailer density within all counties was 0.19 per ten kilometers (km) of roadway (range 0.01-1.03). The densest localities (range: 0.55-1.03 retailers per 10km of roadway) consisted of the four principal cities in the Richmond MSA (Colonial Heights, Richmond, Hopewell, and Petersburg) and Henrico County, which surrounds the north side of the city of Richmond and has the highest area population. These localities also had the highest population density in the MSA and contained the majority of diverse or primarily non-white neighborhoods.

Census Tracts

On average, there were 3.42 retailers per census tract (range = 0.33-8.83; Table 4b.1 and Figure 4b.3). For the SES quartile index variable, quartile 3 had the highest count of retailers with 276, with quartile 1 and 2 both having 263 retailers. Quartile 4, the highest SES quartile however only contained 170 retailers.

Public and Private Schools

The Richmond MSA contains 268 K-12 public schools and 74 private schools with a total student population over 200,000 (Table 4b.2). Figures 4 and 5 are spatial maps of retailers, school locations (public and private), and county lines in the Richmond MSA provided for descriptive purposes.

There was at least one retailer within a half-mile for 45% of Richmond MSA public schools (Table 4b.2). Further, there was at least one retailer within one-mile of 75% of schools and with two-miles, 92% of schools. Using whole radius buffers, the 268 public schools had a total of 396 retailers within a half-mile, 1,453 retailers within one-mile, and 4,960 retailers within two-miles (not mutually exclusive as retailers can be counted more than one time if they overlap with more than one school). On average, public schools had 1.5 retailers within a half-mile, 4.1 within one-mile, and 13.5 within two-miles. Using neighborhood buffers (multi-ring), there were 396 within half-mile, 1,057 between a half- and one-mile, and 3,507 between one- and two-miles.

Among private schools, there was at least one retailer within a half-mile for 72% of K-12 private schools, within one-mile for 87% of K-12 private schools, and within two-miles for 97% of K-12 private schools (Table 4b.2). Using whole buffers, private schools had 235 retailers within half-mile, 658 retailers within one-mile, and 2,028 retailers within two-miles. On average, private schools had 3.2 retailers within half-mile, 8.9 with one-mile, and 27.4 within two-miles. Using neighborhood buffers (multi-ring), there were 235 within half-mile, 423 between half- and one-mile, and 1,370 between one- and two-miles.

Retailer Proximity Counts at Smaller Distances from K-12 Public Schools

Retailer proximity counts were further assessed by applying smaller distance whole radius buffer areas between 100-meters and 1-mile surrounding K-12 public schools. Distances included: 100-, 250-, 500-, 1000-meters, quarter-mile, half-mile, and one-mile (Table 4b.3). Even at very short distances (100 and 250 meters) K-12 public schools had retailers present. As the distance increased, proximity retailer count steadily increased. Between a half-mile and 1000 meters, more schools than half of public K-12 schools in the Richmond MSA had at least 1 surrounding retailer. At a proximity distance of one-mile, 41 schools had more than 11 retailers surrounding the school, with 7 schools having more than 20 retailers within a mile. Even at short distances, over 20% of schools at least 1 retailer with quarter mile and 2 schools had a retailer within 100 meters.

Bivariate analyses

Tobacco/E-cigarette Retailer Density and Counts with Census Tract Diversity

There was a significant difference when examining the average retailer density within census tracts between tract diversity (Table 4b.4). Diverse tracts on average had 0.25 retailers per 10km of roadway which was significantly higher than white (0.15) or non-white tracts (0.19). However, when examining retailer counts, there was a non-significant difference in the average number of retailers between white, non-white, and diverse tracts (range: 3.4-3.5).

Tobacco/E-cigarette Retailer Density and Counts with Socioeconomic Status

Census tracts in the lowest SES quartiles had significant differences for retailer density and counts and displayed contradicting results (Table 4b.4). Average retailer density in the lowest census tract SES quartile (Q1) was significantly higher (0.26 retailers per 10 km of

roadway) versus other quartiles (Q2 = 0.16, Q3 = 0.15, and Q4 = 0.16). However, average retailer counts were significantly lower in the highest SES quartile (Q4 = 2.4) versus other quartiles (Q1 = 3.7, Q2= 3.7 and Q3 = 3.8).

Tobacco/E-cigarette Retailer Proximity Counts around Public Schools

The average number of retailers at each proximity distance (whole radius) around public schools were examined by tract SES, census school diversity, school level, and quartiles of those receiving free/reduced price lunch (Table 4b.5). The average number of retailers surrounding schools in the lowest SES quartile was significantly higher than schools in other quartiles. At half-mile, schools in the lowest SES quartile (Q1) on average had 2.2 retailers compared to schools in quartiles two through four which averaged between 1.2-1.3 retailers. Additionally, the average higher number of retailers around public schools with a diverse student population was significantly higher at all distances (half-mile = 2.3, one-mile=8.2, two-miles= 27.7) compared to schools with a primarily white or non-white student population (half-mile = 0.6-1.0, one-mile=3.0-3.1, two-miles=10.0-12.5). Schools with the most students receiving free/reduced price lunch (quartile four) had a significantly higher average number of retailers at all distances (half-mile = 2.5, one-mile = 9.2, two-miles = 30.0) than schools with fewer students receiving free/reduced price lunch (Q1-3; half-mile = 0.9-1.2, one-mile = 3.4-4.6, two-miles = 12.2-16.0).

Regression Analyses

Associations of Tobacco/E-cigarette Retailer Density and Counts with Socioeconomic Status

Generally, higher retailer density and counts within census tracts was significantly and moderately associated with lower SES by census tract after controlling for tract population (Table 4b.6). Compared to those in census tracts of the highest SES quartile (four), quartiles the

three lowest quartiles (one through three) were significantly associated with higher retailer counts at each level (aOR= 1.86 [95% CI 1.36-2.55]; aOR= 1.55 [95% CI 1.14-2.10]; aOR= 1.68 [95% CI 1.24-2.28]). Conversely for density, compared to the highest SES quartile (four), only tracts in the lowest quartile (one) were significantly associated with higher retailer density (aOR= 1.56 [95% CI 1.08-2.25]).

Associations of Tobacco/E-cigarette Retailer Density and Counts with Tract Diversity

Only one association was found between tobacco/e-cigarette retailer density or count and census tract diversity (Table 4b.6). Higher census tract retailer density was significantly and moderately associated with living in a diverse census tracts compared to living in a primarily white census tract (aOR= 1.93 [95% CI 1.29-2.89]). None of the models for retailer count displayed significant associations.

Associations of Tobacco/E-cigarette Retailer Density and Counts with Socioeconomic Status

To examine the relationship between retailer density and SES further, first, each variable used to create the SES index was examined for associations with retailer density and counts while controlling for tract population (Table 4b.6). Higher retailer density was moderately and significantly associated with lower median income, lower household value, higher percent unemployed, and higher percent in poverty. Among the other variables however, as household median income and value increased, retailer count and density both decreased. Additionally, as the percent in each tract who were unemployed or in poverty increased, retailer density and count also increased. Conversely, higher retailer counts in tracts were moderately and significantly associated with lower median income, lower household value, higher percent unemployed,

higher percent in poverty, and higher percent with less than high school educations (but not for percent college or higher).

Associations of Tobacco/E-cigarette Retailer Proximity Counts Surrounding K-12 Schools

Generally, higher retailer proximity counts surrounding schools was associated with low SES within the school environment (percent receiving free or reduced price lunch) and neighborhood environment (tract SES; Table 4b.7). For school SES, higher retailer counts at a half-mile, one-mile, and two-miles were significantly and moderately associated with schools with the highest quartile of students receiving free or reduced price lunches compared to the lowest quartile (half-mile: aOR= 2.37 [95% CI 1.36-4.15]; one-mile: aOR= 2.14 [95% CI 1.51-3.05]; two-miles: aOR= 2.10 [95% CI 1.56-2.83]). Additionally, examining the percent of students receiving a free or reduced price lunch as a continuous percentage demonstrated significant and moderate associations at all distances (half-mile: aOR= 1.13 [95% CI 1.06-1.21]; one-mile: aOR= 1.12 [95% CI 1.07-1.17]; two-miles: aOR= 1.12 [95% CI 1.08-1.15]) presented in deciles (10% or 10-unit increase interpretation). Having at least one retailer was significantly and strongly associated with the highest quartile of free or reduced price lunch at half- and one-mile distance compared to the lowest quartile (half-mile: aOR= 4.44 [95% CI 2.01-9.80]; one-mile: aOR= 4.80 [95% CI 1.71-13.43]).

For school neighborhood SES, higher retailer counts were significantly and moderately associated with schools being located in the lowest SES quartile tracts compared to schools of the highest quartile (half-mile: aOR= 1.93 [95% CI 1.09-3.41]; one-mile: aOR= 1.82 [95% CI 1.26-2.62]; two-miles: aOR= 1.75 [95% CI 1.30-2.36]). Schools having a retailer within half-mile was significantly and moderately associated with the lowest SES quartile (aOR= 2.30 [95% CI 1.04-5.09]) compared to the highest quartile.

For school diversity, higher retailer counts were significantly and moderately associated with attending a diverse school compared to attending a primarily white school at all distances (half-mile: aOR= 1.93 [95% CI 1.09-3.41]; one-mile: aOR= 1.82 [95% CI 1.26-2.62]; two-miles: aOR= 1.75 95% CI [1.30-2.36]). Schools having one or more retailers within half- or one- mile was significantly and strongly associated with attending a diverse school (half-mile: aOR= 3.47 [95% CI 1.96-6.15]; one-mile: aOR= 4.51 [95% CI 2.14-9.52]) compared to attending a primarily white school.

DISCUSSION

The purpose of this study was to examine tobacco availability surrounding K-12 schools and the relationship between availability and SES in Richmond, VA. Results demonstrated high retailer availability at distances less than two miles surrounding K-12 schools. High retailer proximity counts were associated with attending low SES schools (low SES neighborhood and student population). Furthermore, examination of the entire Richmond MSA demonstrated that high retailer density was associated with low SES census tracts, which is similar to previous research [154]. While this study did not examine the relationship between tobacco availability and use, previous research has demonstrated that high retail density is associated with increased youth initiation and success of cessation attempts [137-139]. Retailer density rates found in this study are similar to studies examining density in relation to tobacco use in other localities [137,155].

Tobacco/E-cigarette Retailers Surrounding Public Schools in Richmond

The vast majority of Richmond K-12 public schools had tobacco/e-cigarette retailers surrounding school locations, highlighting the exposure and access youth have to tobacco/e-cigarette retailers. Retailers being located around schools was expected, particularly at larger

distances such as a mile or two miles; however, it was not expected that an overwhelming proportion of schools had at least one retailer within a half-mile (46%), within 1,000 meters (56%), or within 1-mile (76%). Further, individual schools had a large number of retailers at these larger distances. For example, 18 schools had more than 6 retailers within a half-mile, 38 schools more than 6 retailers within 1,000 meters, and 100 schools more than 6 retailers within one-mile. At a distance of one-mile, 7 schools had more than 20 retailers. Nonetheless, tobacco/e-cigarette retailers surrounded individual schools had retailers even at short distances. At 100 meters, 2 schools had at least 1 retailer, at 250 meters, 25 schools had had at least 1 retailer, and at a quarter-mile 58 schools had at least 1 retailer.

Tobacco/e-cigarette retailer availability was associated with school SES and race. These associations were assessed both with school student populations and at the census tract level. The multivariate analyses in this study demonstrated that higher retailer proximity counts were associated with more students receiving free or reduced price lunches, in addition to schools located in the lowest SES quartile. Schools that were in the highest quartile of percent of students receiving a free/reduced price lunch and were predominantly racially diverse all demonstrated significant associations with proximity counts and having at least one retailer within a half- or one-mile of the school. Additionally, the bivariate analysis of retailer count (whole radius) around schools at half-, one-, and two-miles found significant differences between levels of school SES, school diversity, percent of students receiving free or reduced price lunch.

Among all schools the average retailer count increased as the proximity buffers increased (from a half-mile to a two-mile radius). For the lowest SES and receiving free/reduced price lunch quartiles, average retailer count went from 2.2 to 26.3 and 2.5 to 30.0 surrounding schools. Examining retailer counts using multi-ring buffers still produced extremely large counts of

retailers surrounding schools at each distance interval. While this study did not assess tobacco use or smoking rates, other studies have reported that retail availability is associated directly with youth and young adult initiation and continuation of use[137,138,144,193]. This study however did demonstrate that lowest SES students and students attending lower SES schools have greater tobacco availability around their schools.

Previous research has shown that restricting sales using a “minimum allowable distance from schools” policy can reduce significantly the number and density of tobacco/e-cigarette retailers within a community [144]. Use of the proximity retail counts is a form of a density measure of retailers around schools as the proximity counts are based on distances from each school location. In respect to schools, retailer density was higher surrounding schools that were located in low SES census tracts, had low SES student populations, and were generally diverse in their student demographics. Recent studies have also found a similar relationship [144,148] and have called for attention to be drawn to addressing density around schools as a policy-based tactic for potentially reducing youth exposure to tobacco at the retail level. In turn, addressing density could have an impact on use rates and initiation of tobacco products, particularly for experimental smoking of cigarettes and possibly for e-cigarettes [193].

Use rates for youth were not assessed in this study as these data do not exist at the census tract or county level for the Richmond MSA and thus, this study cannot claim that reducing retail availability would reduce youth smoking in Richmond. Based on the results of this study, no comparison can be made directly between tobacco availability and use. Doing so would perpetuate an ecological Fallacy. However, this study does however demonstrate that retailer availability is higher for low SES and racially diverse youth, which often are considered vulnerable populations for tobacco initiation [194]. Previous work has demonstrated that the

relationship between individual smoking and retailer density is modified by an individual's SES and their neighborhood SES [161]. Higher density counts in low SES areas may lead to more access and therefore initiation and use among vulnerable youth populations.

Tobacco/E-cigarette Retailers in Richmond

Across the Richmond MSA, there was one retailer per 1,244 residents (range: 675-7,154) and an average of 3.4 retailers in each census tract. Retailer density (retailers per 10km roadway) was highest in the four principal cities (Colonial Heights, Richmond, Hopewell, and Petersburg) and Henrico County (range = 0.55-1.03) compared to other localities (cities and counties) (range = 0.01 – 0.31). Comparatively, retailer density in principal cities within the MSA were similar to other studies in other localities [146,154,177]. For example, Cantrell et al. reported a retailer density of 0.38 retailers per 10km of roadways in the MSA's selected for their nationwide study. However, the MSA's of interest in that study had a much higher average population density [137] which could account for the difference. To assess retailers in any locality properly, density is the preferred measure, particularly one that accounts for population and land area such as 10 kilometers of roadway. In our study, the average number of retailers or counts within census tracts provided biased results as rural localities with low retailer shop count and low overall density demonstrated high mean counts of retailers. High retailer counts in rural areas most likely indicates that rural localities have a few census tracts and a small number of them may have significant proportion of retailers. Additionally, examination of differences in retailer count by urbanicity or rurality within the study area, could also have provided biased results due to a small number of localities and similar biased results of the average number of retailers.

Tobacco/E-cigarette Retailers and Socioeconomic Status within Census Tracts in Richmond

This study found moderate associations between tobacco availability and SES within census tracts. The multivariate analysis demonstrated that there were significant associations between SES quartiles and retailer count and density, in addition to tract diversity and retailer density. Compared to SES quartile four (highest), all three lower quartiles demonstrated significant associations with retailer count, but when examining retailer density, only the lowest quartile had a significant association. The difference in the significant associations between SES quartiles when examining counts versus density supports the notion that retailer density is the superior measure, which is supported by other research [161]. Previous research has established that there is greater density of tobacco availability in areas where individuals tend to be less healthy and have higher proportions of non-white populations [146-149]. While this study did not examine health or behavior outcomes, the results found within the Richmond MSA census tracts confirm that counts and density are higher in low socioeconomic areas, particularly for lower income, lower home value, higher unemployment, and higher poverty.

Bivariate analyses examining average retailer count and average retailer density for SES and diversity within tracts also demonstrated that retailer density is a superior and more consistent measure. For retailer counts, census tracts with that were the highest SES quartile had a significantly lower average number of retailer compared to those in the lowest three quartiles. Comparatively, the significance reversed when examining retailer density as those in the lowest SES quartile had a significantly higher retailer density compared to other quartiles. This result was what was originally hypothesized and because density accounts for land and population by calculating the number of retailers per 10 km of roadway, is the less biased measures compared

to counts. Significant differences were expected to be found between the highest and lowest SES census tracts, however the average number of retailers (counts) for census tracts in the middle quartiles (Q2 and Q3) and the lowest quartile (Q1) were not different. The significant differences reversed when examining density, as the middle quartiles (two and three) were not different and were similar to the highest quartile (Q4). The produced results by SES level were all very similar to the average retailer count and density in the entire Richmond MSA (3.4 for counts and 0.19 for density). There were no differences in the average number of retailers among census tract racial groups, however there were significant differences when examining density. It was expected that census tracts that predominantly were non-white or diverse, would have a higher average retailer counts, which held true for diverse tracts having a significantly higher retailer density. Average density of retailers in non-white tracts did not differ significantly from white tracts.

Future Work and Notes

Future work examining tobacco retail outlets in comparing different localities could employ a similar data collection strategy as this study, allowing for an examination of the relationship between tobacco availability, tobacco use, and SES, while controlling for sociocultural aspects and local or state policy. The results of this study provide similar evidence to other research addressing community environment such as community health indicators, availability of healthy food, and the influence an individual's area has on health[148,180,187,188]. Thus, the availability of tobacco products could be a key community health indicator for individuals living within census tracts containing high retail density in the Richmond MSA. Future public health research and action may find it useful to monitor tobacco retail density and counts as a community health indicator and thus a potential point of regulation. From a policy

perspective, tobacco retail counts and density are potentially valuable information for policy and planning purposes. Localities that do not monitor retailers do not have the benefit on information that potentially impacts community environments directly and could serve as a proxy health measure.

This study indicates that retailers such as convenience stores or gas stations may be more important when examining retailer availability, particularly in relation to youth and young adult use and for policy and regulatory purposes. Much of the attention around e-cigarettes has been for vape shops, however they resulted in only being a small proportion of retailers in Richmond using this studies data collection technique. Collecting availability data from e-cigarette brand websites allowed for examination of the frequency of brands in localities. Overall, Blu e-cigarettes were in a total of 89% of locations collected in this study. However, among other brands the next highest proportion of brand availability was only 19% (NJOY and v2). Interestingly, the use of Yelp and Google produced approximately 5% (n=47) of the retailers collected for this study and commonly were "vape shops" or retailers that sell specialty e-cigarette products such as "Mods" (e-cigarettes that have been modified or changed) and e-liquids.

Study Limitations

This study has several important limitations to consider. First, this study collected data from e-cigarette brand websites to be used as a proxy for tobacco locations in the Richmond, VA MSA. It was assumed that any location carrying these brands, would also carry tobacco products as many retailers have contracts with tobacco companies [195]. The possibility also exists that the data obtained are an extremely conservative estimate of the actual number of locations within the MSA due to using e-cigarette retailers as the proxy measure. Second, only six major brands

were selected for data collection. These brands however, appear to be the most popular cig-a-like brands or owned by major tobacco industry corporations. Third, the data were collected over a two-week period, and only once. E-cigarettes have grown in popularity over time. Fourth, this study did not validate that products were actually carried in store, but did validate that locations existed using Google Street view for half of the sample. Fifth, recent deeming policy by the Food and Drug Administration could reshape e-cigarette availability by consolidating the overall e-cigarette market, which could limit the value of future data collection methods used in this study. Sixth, the geographic units of observation in this study were considered independent rather than being spatially dependent. Lastly, while the Richmond, VA MSA is a fairly representative city, generalization of this study's results may not be representative for other cities or MSAs across the US.

Implications and Conclusions

There are a few important implications from this study. First, retailer density in this study was higher in lower socioeconomic census tracts within the Richmond MSA and similar disparities in use between socioeconomic status and tobacco use in the Richmond area could also exist. Previous work has examining tobacco availability and tobacco use often examine socioeconomic or sociodemographic factors as confounders or interactions within the relationship. Additionally, few studies have examined the association between availability and socioeconomic status [149,189].

Second, tobacco and e-cigarettes are widely available in neighborhoods surrounding K-12 public schools in Richmond, particularly those in low SES neighborhoods and low SES student populations. Retailer proximity counts were significantly higher surround schools in low SES tracts, diverse schools, and schools with high percentages of students receiving free or

reduced price lunches. Previous work has shown that that reducing tobacco density surrounding schools in low socioeconomic areas can reduce socioeconomic and racial disparities in use [190]. From a policy perspective, reducing or controlling the number of retailers in low socioeconomic areas could potentially have an effect on overall use rates among youth populations that are highly vulnerable. Previous studies have established that high retailer density around is associated with youth smoking and demonstrated similar density and retailer count results as this study [138,158,162,190,193]. While the results from this study has implications for policy regarding K-12 schools, it may also have implications for higher education institutions. As demonstrated in the previous chapter (2a), higher education institutions had higher retailer counts and density than other areas of the Richmond MSA. K-12 schools in the Richmond demonstrated similar results and the addition of examining SES in relation to tobacco availability highlight that tobacco density could be assessed as a community health issue.

Table 4b.1. Tobacco/E-cigarette Retailers and Characteristics of the Richmond, Virginia Metropolitan Statistical Area

	Tobacco/E-cigarette Retailers				Population Density[b]		SES Index Quartile Tract Count[c]				Race Composition Tract Count[d]		
County/City	**Retail shops**	**Density[a]**	**Residents per retailer**	**Mean retailers within tract**	**Census Tracts**	**Residents per sq. mile**	**SES 1**	**SES 2**	**SES 3**	**SES 4**	**White**	**Non-White**	**Diverse**
Colonial Heights City	26	1.03	675	5.20	5	2,358	1	2	2	0	5	0	0
Richmond City	194	0.88	1073	2.98	65	3,643	28	10	9	18	23	12	30
Hopewell City	24	0.70	932	4.00	6	2,159	4	2	0	0	2	2	2
Henrico County	241	0.59	1285	3.75	61	1,378	9	17	13	22	38	9	14
Petersburg City	38	0.55	854	3.45	11	1,426	8	2	1	0	0	0	11
Chesterfield County	209	0.31	1552	2.94	71	785	9	18	20	24	53	12	6
Hanover County	84	0.14	1199	3.65	23	218	0	2	15	6	23	0	0
New Kent County	23	0.11	834	7.67	3	95	0	0	3	0	3	0	0
Powhatan County	20	0.09	1410	4.00	5	109	0	1	4	0	4	0	1
Caroline County	33	0.07	881	4.71	7	56	2	5	0	0	6	1	0
Goochland County	15	0.06	1442	3.00	5	81	1	0	2	2	4	0	1
Prince George County	18	0.06	2044	2.57	7	141	1	4	2	0	4	3	0
King William County	12	0.05	1337	3.00	4	59	0	3	1	0	3	1	0
Dinwiddie County	23	0.04	1217	8.83	6	55	3	3	0	0	4	2	0
Sussex County	16	0.04	648	4.00	4	24	4	0	0	0	1	2	1
Amelia County	7	0.02	1823	3.50	2	36	0	2	0	0	2	0	0
Charles City County	1	0.01	7154	0.33	3	38	2	1	0	0	0	2	1
Total or Average	**984**	**0.19**	**1244**	**3.42**	**288**	**276**	**72**	**72**	**72**	**72**	**175**	**46**	**67**

Notes:

a. Density = Retailers per 10km of roadway in census tract

b. 2014 American Community Survey

c. Tract SES index based on factor analysis of 6 variables including: % unemployed, % below poverty threshold, % less than high school education, % college education or higher, median tract household value, household median income. Factor analysis used to create quartile scores

d. Categories may not add up to 100% because reporting did not capture categories of multiple race/ethnicities

Table 4b.2. Characteristics of Schools Tobacco/E-cigarette Retailer Proximity Counts and in the Richmond, VA MSA			
	Public Schools	**Private Schools**	**All Schools**
Total Schools	268	74	342
School Level			
Primary	170	35	205
Middle	53	-	53
Secondary/Combined	45	39	84
Student Population	195,470	13,712	209,182
Average School Population Size (SD)	729 (365)	185 (246)	626
Schools within Census Tract SES Quartiles			
SES 1	50	13	63
SES 2	72	19	91
SES 3	72	11	83
SES 4	66	31	97
School Race Composition			
% White	40.8%	55.4%	-
% Non-White	18.1%	17.6%	-
% Diverse	41.2%	27.0%	-
% Receiving free or reduced price lunch	37.7%	-	-
Retailer Count:			
< 0.5 mile[a]	396	235	631
< 1-mile[a]	1,453	658	2,111
< 2-miles[a]	4,960	2,028	6,988
> 0.5 and ≤ 1 mile[b]	1,057	423	1,480
> 1 and ≤ 2 miles[b]	3,507	1,370	4,877
Average number of retailers per school			
< 0.5 mile[b]	1.5	3.2	1.0
< 1-mile[a]	4.1	8.9	3.4
< 2-miles[a]	13.5	27.4	11.2
Percent schools with ≥ 1 retailer			
< 0.5 mile[a]	45.4%	71.6%	51.2%
< 1-mile[a]	75.8%	86.5%	77.9%
< 2-miles[a]	92.3%	97.3%	93.4%
Average tract retailer count (SD)			
with school***	3.60 (2.90)	3.75 (2.97)	3.60 (3.28)
without school***	3.05 (3.34)	3.28 (3.22)	2.90 (2.91)
Average tract retailer density (SD)			
with school***	0.19 (0.21)	0.23 (0.24)	0.18 (0.21)
without school***	0.12 (0.23)	0.17 (0.21)	0.18 (0.21)

Notes:
a. Whole Radius buffer = Not mutually exclusive
b. Multi-ring buffer = Mutually exclusive
***Not significantly different between tracts with or without schools at p=0.05

Table 4b.3. Tobacco/E-cigarette Retailer Proximity Counts at Various Distances Surrounding K-12 Public Schools in the Richmond MSA

100 Meters		250 meters		0.25 mile		500 meters		0.5 mile		1000 meters		1 mile	
Retailer Count	# of Schools	Retailer Count	# of Schools	Retailer Count	# of Schools	Retailer Count	# of Schools	Retailer Count	# of Schools	Retailer Count	# of Schools	Retailer Count	# of Schools
0	266	0	243	0	210	0	193	0	145	0	118	0	65
1-5	2	1-5	25	1-5	56	1-5	72	1-5	104	1-5	112	1-5	103
				6-10	2	6-10	3	6-10	17	6-10	32	6-10	59
								11-15	2	11-15	4	11-15	22
										16-20	2	16-20	12
												20+	7

Notes:

a. Retailer proximity count = Whole radius retailer proximity count surrounding schools not mutually exclusive between distances (i.e. larger distances include counts from smaller distances)

Table 4b.4. Bonferroni Pairwise Comparisons of Average Number of Retailers for Tracts in Richmond, VA MSA

	Count[c]	**Density**[d]
Tract SES Quartiles[a]		
1 (lowest)	3.7	**0.26****
2	3.7	0.16
3	3.8	0.15
4 (highest)	**2.4****	0.16
Tract Diversity[b]		
White	3.5	0.15
Non-white	3.4	0.19
Diverse	3.5	**0.26****

Notes:

e. SES index: higher quartile, better SES score (i.e. higher SES)
f. Diversity: White >60%, Non-white >60%, Diverse <60% both
g. Count = Whole radius buffer
h. Density = retailers per 10km of roadway in census tract

Table 4b.5. Bonferroni Pairwise Comparisons of Average Number of Retailers for Tracts in Richmond, VA MSA

	Public Schools		
	Count 0.5-mile	**Count 1-mile**	**Count 2-miles**
School Tract SES Quartiles[a]			
1 (lowest)	**2.2****	**7.8****	**26.3****
2	1.2	5.3	17.8
3	1.3	4.2	14.6
4 (highest)	1.2	4.2	14.6
School Diversity[b]			
White	1.0	3.1	10.0
Non-white	0.6	3.0	12.5
Diverse	**2.3****	**8.2****	**27.7****
School Level			
Primary	1.4	5.3	18.4
Middle	1.7	5.1	16.5
Secondary/Combined	1	4.9	16.5
% Students receiving free/reduced price lunch Quartiles[c]			
1 (most)	**2.5****	**9.2****	**30.0****
2	1.2	4.6	16.0
3	1.0	3.2	12.5
4 (fewest)	0.9	3.4	12.2

Notes:
** Indicates Significant Difference
a. SES index: higher quartile, better SES score (i.e. higher SES)
b. Diversity: White >60%, Non-white >60%, Diverse <60% both
c. RFRPL: higher quartile, more students receiving free/reduced price lunches

Table 4b.6. Multivariate Analysis of Tobacco/E-cigarette Retailers and Census Tracts in Richmond, VA MSA

		Count			Density[a]		
		aOR	95% CI	p-value	aOR	95% CI	p-value
Tract SES Quartiles[c]	1	**1.86**	**1.36-2.55**	**<0.01**	**1.56**	**1.08-2.25**	**<0.01**
	2	**1.55**	**1.14-2.10**	**0.01**	0.98	0.65-1.48	0.93
	3	**1.68**	**1.24-2.28**	**<0.01**	0.93	0.61-1.40	0.71
	4 (ref)	-	-	-	-	-	-
Diversity[g]	White (ref)	-	-	-	-	-	-
	Black	1.11	0.82-1.50	0.50	1.26	0.85-1.85	0.25
	Diverse	1.13	0.87-1.47	0.36	**1.68**	**1.23-2.28**	**<0.01**
SES variables[cdef]	% Unemployed	**1.47**	**1.01-2.16**	**0.05**	**1.93**	**1.29-2.89**	**<0.01**
	% In poverty	**1.18**	**1.06-1.30**	**<0.01**	**1.30**	**1.19-1.41**	**<0.01**
	% Household value	**0.86**	**0.78-0.95**	**<0.01**	**0.87**	**0.76-0.99**	**0.03**
	% Income[d]	**0.80**	**0.74-0.88**	**<0.01**	**0.72**	**0.64-0.80**	**<0.01**
	% Less than HS grad	**1.15**	**1.02-1.29**	**0.02**	1.13	0.99-1.28	0.06
	% College or higher	0.95	0.90-1.01	0.08	1.04	0.97-1.11	0.28

Notes:

a. Density = retailers per 10 km of roadway within census tracts
b. All models control for Tract Population
c. SES = Socioeconomic Status, SES index: higher quartile, better SES score (i.e. higher SES)
d. Range of variable 0-100%
e. Percent of highest tract median value
f. Continuous variables presented in deciles (10% or 10-unit increase interpretation)
g. Diversity: White >60%, Non-white >60%, Diverse <60% both

Table 4b.7. Multivariate Analysis of Tobacco/E-cigarette Retailers and Public Schools in Richmond, VA MSA

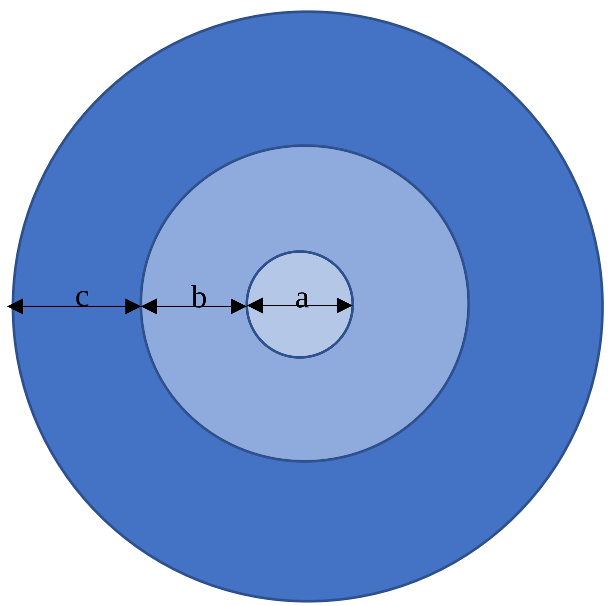
		Count 0.5 mile			Count 1 mile			Count 2 mile			0.5 mile: at least 1 retailer			1 mile: at least 1 retailer			2 miles: at least 1 retailer		
		aOR	95% CI	p-value	aOR	95% CI	p-value	aOR	95% CI	p-value	aOR	95% CI	p-value	aOR	95% CI	p-value	aOR	95% CI	p-value
Free Reduced Price Lunch Quartiles	1 (ref)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2	1.05	0.60-1.86	0.86	0.82	0.58-1.18	0.28	0.88	0.66-1.17	0.37	1.58	0.74-3.36	0.54	1.30	0.60-2.81	0.23	0.90	0.20-3.99	0.72
	3	1.32	0.75-2.31	0.34	1.22	0.86-1.74	0.26	1.24	0.93-1.65	0.15	1.54	0.72-3.27	0.46	1.56	0.71-3.43	0.63	0.43	0.11-1.60	0.11
	4	**2.37**	**1.36-4.15**	**<0.01**	**2.14**	**1.51-3.05**	**<0.01**	**2.10**	**1.56-2.83**	**<0.01**	**4.44**	**2.01-9.80**	**<0.01**	**4.80**	**1.71-13.43**	**<0.01**	0.90	0.19-4.20	0.73
Free Reduced Price Lunch %[b]		**1.13**	**1.06-1.21**	**<0.01**	**1.12**	**1.07-1.17**	**<0.01**	**1.12**	**1.08-1.15**	**<0.01**	**1.18**	**1.05-3.29**	**<0.01**	**1.19**	**1.06-2.38**	**<0.01**	0.98	0.46-2.81	0.81
School Diversity[d]	White (ref)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Black	0.60	0.33-1.09	0.09	1.02	0.72-1.45	0.91	**1.34**	**1.02-1.75**	**0.03**	0.70	0.32-1.51	<0.01	1.27	0.61-2.67	0.17	0.56	0.18-1.72	0.16
	Diverse	**2.14**	**1.41-3.25**	**<0.01**	**2.30**	**1.76-3.02**	**<0.01**	**2.55**	**2.05-3.16**	**<0.01**	**3.47**	**1.96-6.15**	**<0.01**	**4.51**	**2.14-9.52**	**<0.01**	1.38	0.46-4.16	0.24
Tract SES Quartiles[e]	1	**1.93**	**1.09-3.41**	**0.02**	**1.82**	**1.26-2.62**	**<0.01**	**1.75**	**1.30-2.36**	**<0.01**	**2.30**	**1.04-5.09**	**0.03**	1.78	0.70-4.48	0.44	0.25	0.06-1.10	0.03
	2	1.15	0.67-1.97	0.61	1.34	0.96-1.87	0.08	1.30	1.00-1.70	0.05	1.34	0.67-2.69	0.97	1.34	0.63-2.86	0.87	0.35	0.09-1.42	0.16
	3	1.13	0.66-1.94	0.65	1.03	0.73-1.44	0.87	1.05	0.81-1.38	0.70	1.08	0.53-2.18	0.29	1.60	0.72-3.52	0.27	1.48	0.23-9.46	0.12
	4 (ref)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
School Level	Primary (ref)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Middle	1.40	0.81-2.41	0.23	1.06	0.75-1.51	0.73	0.92	0.69-1.22	0.57	1.57	0.79-3.12	0.46	1.16	0.52-2.58	0.97	0.45	0.14-1.47	0.83
	Secondary/Combined[c]	0.94	0.46-1.93	0.86	1.25	0.79-1.96	0.34	0.97	0.67-1.39	0.85	1.50	0.63-3.61	0.66	1.31	0.45-3.81	0.70	0.26	0.07-0.91	0.10

Notes:
a. All models adjusted for student enrollment
b. Continuous variables presented in deciles (10% or 10-unit increase interpretation)
c. Secondary and combined (primary and secondary) aggregated
d. Diversity: White >60%, Non-white >60%, Diverse <60% both
e. SES = Socioeconomic Status, SES index: higher quartile, better SES score (i.e. higher SES)
f. Estimates in bold are significant at p>0.05

Figure 4b.1. Buffer Types and Distances for Measuring Tobacco/E-cigarette Retailer Count

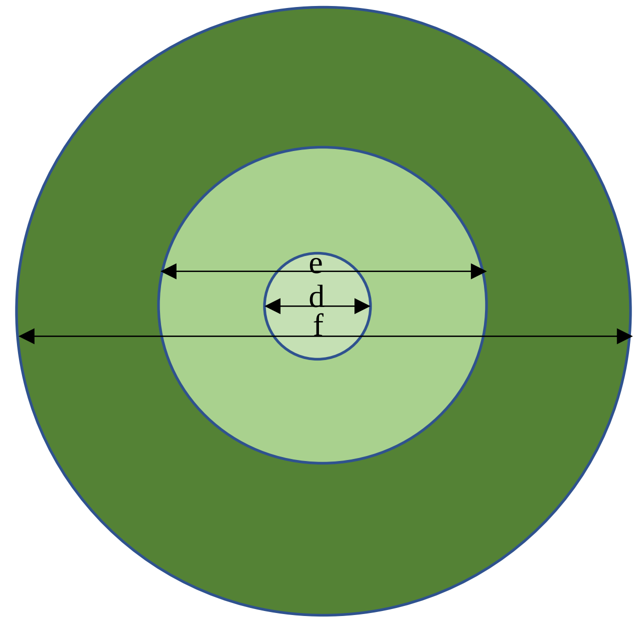
Buffer types used in this study surrounding K-12 schools in the Richmond for spatially determining retailer counts. Use of these buffers in addition to the retailer counts is a form of a density measure as the buffers are built on distances from each campus.

<u>Multi-ring (concentric) Buffer</u>



d. ≤ 0.5 mile
e. > 0.5 mile, but ≤ 1.0 mile
f. > 1 mile, but ≤ 2.0 miles

<u>Whole Radius Buffer</u>



d. ≤ 0.5 mile
e. ≤ 1.0 mile
f. ≤ 2.0 miles

Figure 4b.2. Tobacco/E-cigarette Locations within Counties of the Richmond, VA MSA

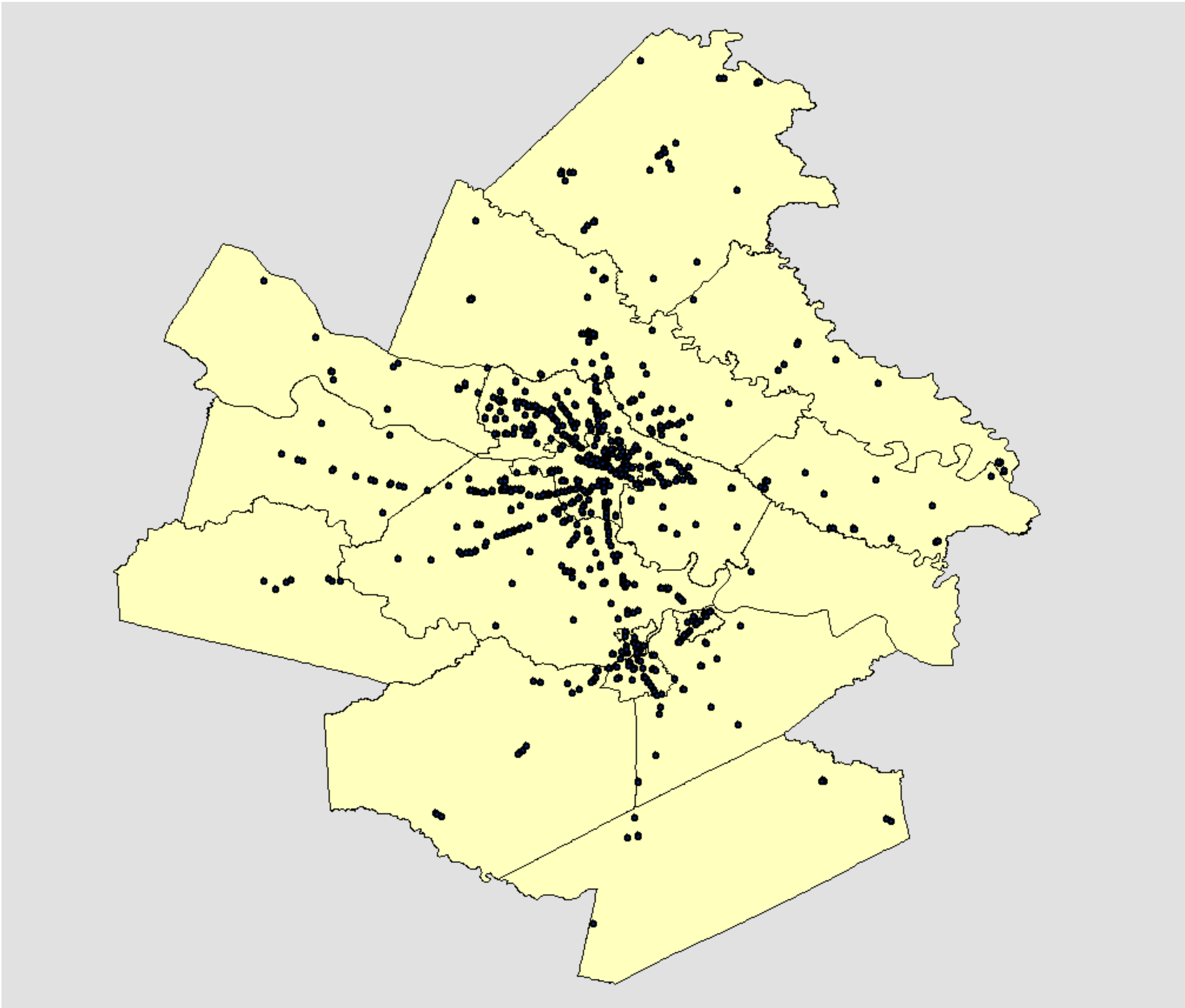


Figure 4b.3. Tobacco/E-cigarette Locations within Census Tracts of the Richmond, VA MSA

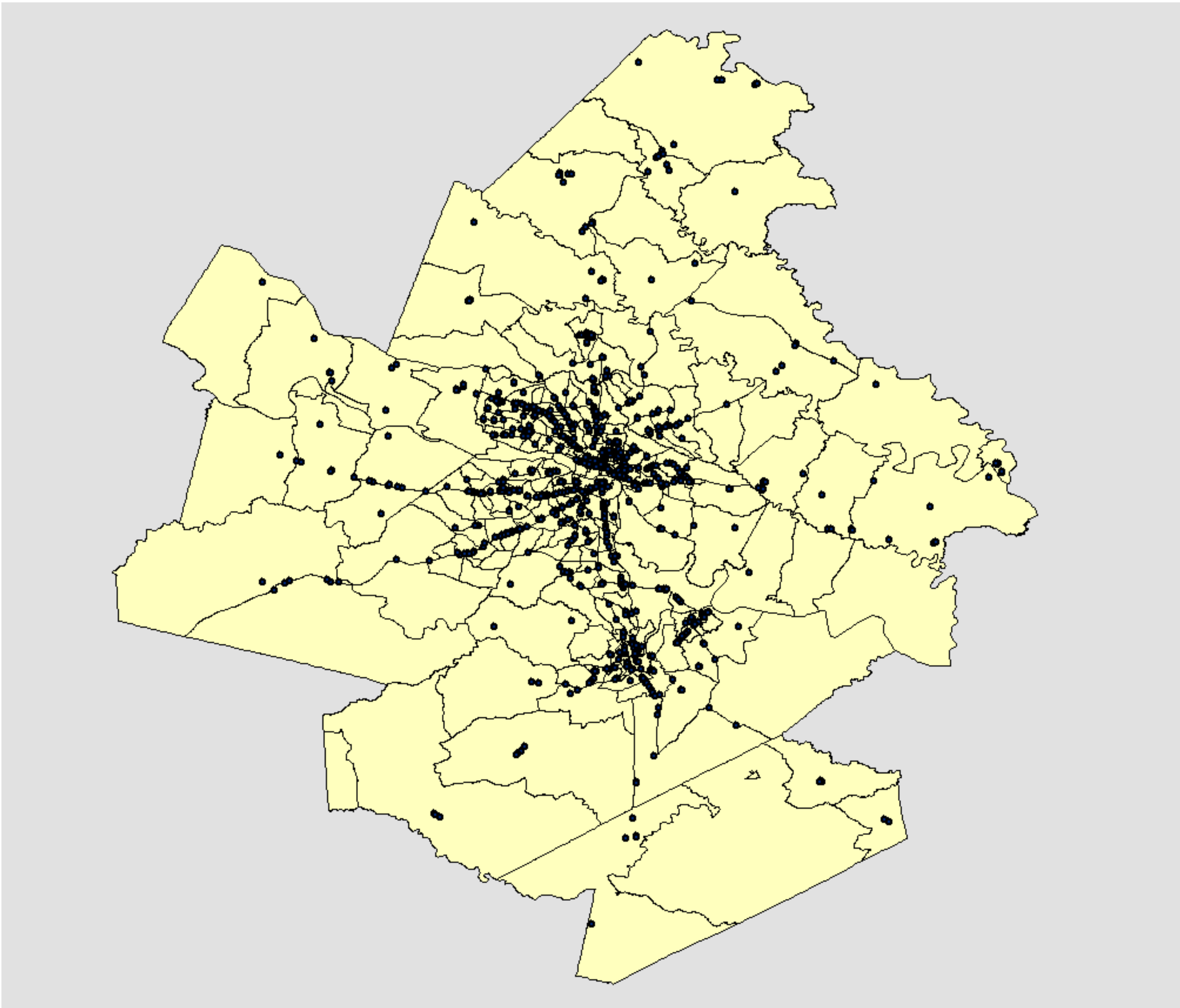


Figure 4b.4. Tobacco/E-cigarette Locations and Buffers Around Public Schools within Counties of the Richmond, MSA

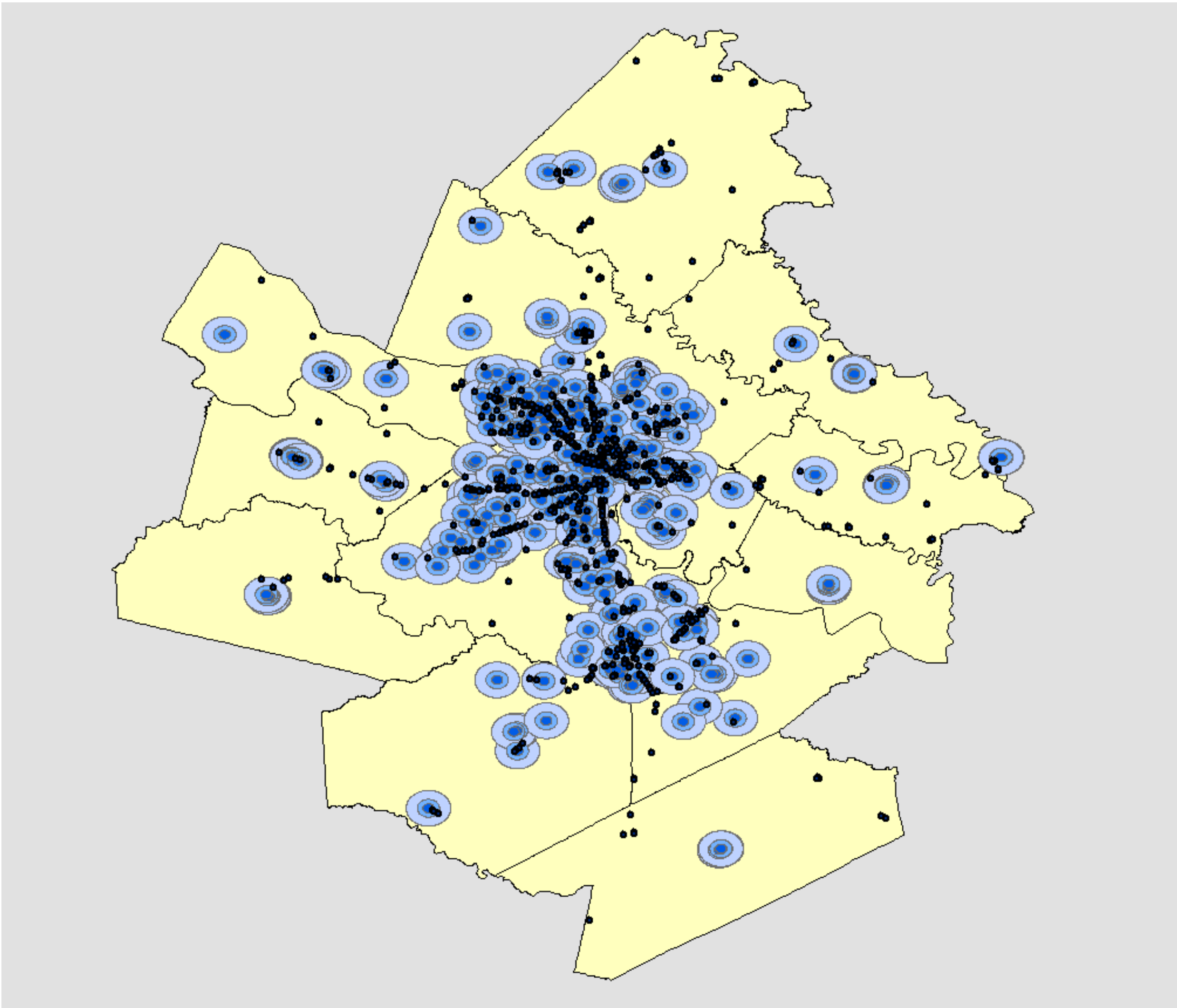
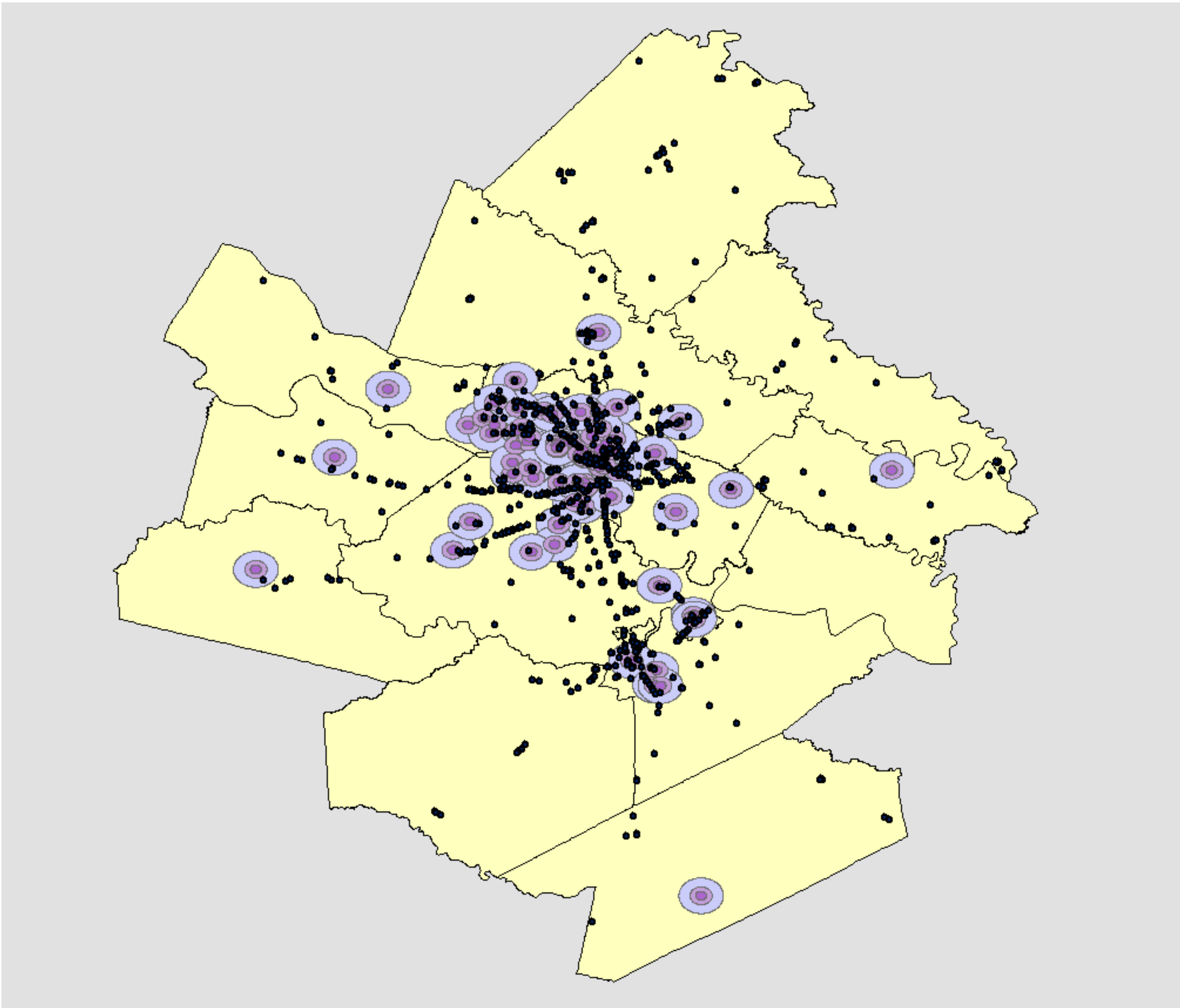


Figure 4b.5. Tobacco/E-cigarette Locations and Buffers Around Private Schools within Counties of the Richmond, MSA



CHAPTER 5: Discussion

Summary

The extent of literature of college tobacco use is extensive, however new products are continuing to change the landscape of college tobacco use. New products such as e-cigarettes or dissolvable tobacco and alternative tobacco products such as hookah or cigars are increasingly becoming popular in college students. Additionally, users are often not using just a single tobacco product, but also commonly use alcohol and marijuana. Findings from this dissertation have implications for policy related to college tobacco use and tobacco interventions and education provided to students. The goal of this dissertation was to examine socioecological aspects of tobacco use in college students including: trends of tobacco behaviors and perception of peer tobacco use (chapter 1), combinations of polysubstance and polytobacco use (chapter 2), and tobacco availability around college campuses (chapter 3). Tobacco use in college populations is highly complex with factors that are often interrelated and interdependent. This dissertation sought to specifically provide opportunities to examine factors related to the personal and community environment and highlighted the important connections that exist between socioecological factors of tobacco use in college populations.

Trends of Tobacco and Polytobacco use and Associations with Perceived Peer Tobacco use

Chapter 2, entitled “Trends of Tobacco and Polytobacco use and Associations with Perceived Peer Tobacco use” examined how trends of tobacco use and perceived peer tobacco in a national US college population change over time. This chapter included trends of single tobacco use (cigarettes, hookah, cigars, smokeless tobacco, and e-cigarettes) and polytobacco use (concurrent or simultaneous used of tobacco within a time period). Descriptive analysis, linear, and logistic regression were used to determine the slope of trends and associations between self-reported tobacco use, perceived peer tobacco use, and demographic/student characteristics from

seven years of the National College Health Assessment II. Trends were assessed separately for males and females. Overall, 23% of the sample used at least one tobacco product in the last 30 days, however rates of single-product and polytobacco use declined over the study period. Approximately 8% of the sample were polytobacco users, using two or more products in the last 30 days. For most tobacco products, males had significantly higher rates of tobacco use and the prevalence of male polytobacco use was twice the rates of females. While males had much higher overall rates of use, they also had larger declines in tobacco use. For non-tobacco substances including alcohol use, binge drinking, and marijuana use, males had higher overall rates of use and were more likely to be more frequent users. Alcohol use in males and females showed small declines in use, however marijuana use over the study period increased. Perception of peer use of tobacco and other substance use followed similar declining trends to self-reported use. Nonetheless, perception of peer use was strongly associated with single-product and polytobacco use in males and females. Among the associations with polytobacco use, alcohol and marijuana use were the strongest. In general, polytobacco use was moderately and significantly associated with low GPA, living off campus and participating in a Greek organization in males and females. Both groups however, had predictors of polytobacco use specific to a gender. Lastly, polytobacco use was assessed by each tobacco product. Cigarettes were the most used tobacco product among polytobacco users for males and females with hookah and cigars being the next most common. Interestingly, e-cigarettes were the third most common polytobacco product used in females. Due to their increasing popularity, it is expected that e-cigarettes may become more popular among polytobacco users in the near future.

Combinations of Tobacco, Alcohol, and Marijuana use in College Students

Chapter 3, entitled "Combinations of Tobacco, Alcohol, and Marijuana use in College Students", utilized separate latent class analyses to examine combinations of tobacco, alcohol, and marijuana use for males and females. The purpose of this chapter was to determine the most likely or probable combinations of polysubstance use in college students. Based on previous work, it was expected that these classes could differ for males and females [23,53], thus separate latent class analyses were conducted. Rates of tobacco, alcohol, and marijuana use in this study were similar to rates found in chapter 2. Both groups contained a class of non-users or "Global Abstainers", which accounted for about 40% of both male and female samples. Overall, the genders had both similar and different classes. A greater proportion of males belonged to polysubstance classes, particularly for tobacco and marijuana and included a class of "Poly-users" who took part in use of each substance was present in males. The poly-use class in males however was missing for females. Alcohol played a significant role in creation of the classes as both groups had a class of alcohol users who binge drink. The proportion of alcohol users who binge drink was much higher for males. Females however, had a large class of alcohol users who do not binge drink, which was missing from males. Polysubstance use of tobacco, alcohol, and marijuana in males and females was associated with being white, having a low GPA, living off campus, and participating in a Greek organization. Future work could re-run similar analyses examining only tobacco products to determine the potential true combinations of polytobacco use in college students and associations between polytobacco classes and alcohol and marijuana use.

Tobacco/E-cigarette Availability around College Campuses and in Neighborhoods of Richmond, VA

The final chapter, Chapter 4, was entitled "Tobacco/E-cigarette Availability around College Campuses and in Neighborhoods of Richmond, VA" examined tobacco/e-cigarette availability in the neighborhood environment surrounding colleges and universities in the Richmond, VA Metropolitan Statistical Area (MSA). The purpose of this chapter was to describe the availability of tobacco/e-cigarettes around college campuses and in census tract neighborhoods and the relationship between availability and socioeconomic status. Data was collected from popular e-cigarette "cig-a-like" brand websites, which were considered to be tobacco retailers for the purposes of this study. Examination of the data revealed that a large majority of these retailers were gas stations, grocery stores, or convenience marts which carry multiple tobacco product types [39]. A total of 984 retailers were found in the Richmond MSA accounting for a retailer density of 0.19 retailers per 10km of roadway. Comparatively, this result is similar to previous work [137] in other localities. There were only 11 college campuses in the Richmond MSA, limiting the comparisons that could be made. Additionally, no data on use rates among these college campuses was available to make comparisons between use and availability. Nonetheless, among the 11 campuses, there were 95 retailers within a half-mile, 219 within one-mile, and 384 within two-miles using whole radius buffers. Tobacco/e-cigarette retailer density was much higher in lower socioeconomic status (SES) neighborhoods, particularly in those with increased poverty and unemployment and decreases household value and income. Census tracts with college campuses and campuses within more urban census tracts had higher overall counts (no significance testing). Due to the small number of campuses, this study was extended to examine tobacco availability around K-12 public schools. On average, there were 1.5 retailers

within a half-mile of a K-12 public school, 4.1 within one-mile, and 13.5 within two miles. Schools that were in the lowest SES tracts and schools with more students receiving free or reduced price lunches had a higher retailer density surrounding the schools. Future work with this study could expand the overall study area to include a greater sample of college campuses and utilize a similar data collection technique to examine availability around universities and colleges. Additionally, selection of another study area with data available on tobacco use would allow for assessment of the relationship between tobacco availability, use, and socioeconomic status in college populations.

Implications for Public Health

The landscape of tobacco use in college populations is changing. The introduction of new products and behaviors had provided college students with alternative tobacco products to use that are becoming more available. College student use of these products, including hookah, cigars, smokeless tobacco, and e-cigarettes is shifting overall use patterns of traditional tobacco use as these products are increasingly becoming the first product tried [21] and use is occurring in a nondaily pattern [71,108,111] resulting in a "diversification" of tobacco products being used. The results of study 1 suggest that tobacco use overall is decreasing in college populations, however, a significant proportion of tobacco users use more than one product, placing them at high risk of negative outcomes such as nicotine dependence and other substance use. The polysubstance use groups from study 2 suggest that educational programs and interventions providing services on college campuses may need to address tobacco, alcohol, and marijuana use differently for males and females. The differing combinations and frequency of use between males and females suggests they have different risk factors for poly-use. Addressing multiple substance use in addition to specific combinations could increases the effectiveness of programs. The availability

of tobacco in chapter 3 suggests that college populations have access to tobacco in neighborhoods surrounding campuses. While there has been a strong national push to addressing tobacco use on campus through policies restricting use, the results from chapter 1 and 2 suggest that living off campus is a risk factor for tobacco use. Thus, campuses need to work with local planning authorities and decision makers to address where tobacco can be sold in neighborhoods where students commonly live.

Future Research

Future research could be aimed at continuing to develop a better understanding of new tobacco product initiation in college populations with the additional target of reducing use. The related behaviors between tobacco, alcohol, and marijuana use place college students at higher risk for dropping out, development of mental health issue, and other negative outcomes that can affect various aspects of their lives after college, including employment. The results from this dissertation suggest that while tobacco use overall has decreased in college students, many students are diversifying their tobacco use to other non-cigarette products and that tobacco is readily available for purchase around college campuses. Additional research is needed to determine the specific choices individuals in college make that determine their overall use or non-use trajectory, particularly among multiple tobacco product or substance users. This includes determining the combinations of tobacco use most likely to occur in college populations and how students transition from product to product, including assessing where alcohol and marijuana fit into the transition. Addressing use of tobacco, alcohol, and marijuana could have a snowball effect in regard to college health outcomes due to the strong influence that substances use has. While most efforts to address tobacco and other substance use has been on campus, institutions need to reach out to students beyond the campus boarders to effect changed in neighborhoods

surrounding campuses where many students live. This include working with local policy makers on restricting where tobacco and other substances can be sold in an effort to limit distribution of products. More research however is needed to assess exactly where these products are being sold around college campuses to have the maximum potential effect on use. Additional policies such as increasing prices of products sold surrounding campuses or raising the purchase age may continue to help drive down rates of tobacco use. These types of policies to date have been enacted in two states (HI and CA) in addition to various localities for tobacco. With the legalization of marijuana, 21 will continue to be the age of purchase in newly legalized states.

Conclusions

College provides a significantly opportunity to address both uptake of tobacco behaviors and cessation treatment for those currently using. At no other time in adulthood are individuals potentially more accessible to receive interventions providing prevention and education than in college. Due to the co-occurrence of tobacco and substance use with other college health issues such as mental health, colleges could provide comprehensive programs on the impact of these issues. Besides the youth time period, college and young adulthood are an ideal time period to assist in establishment of lifelong healthy behaviors. The results from this dissertation provide clear evidence that tobacco use in college populations is changing. While use rates have declined, users are using less frequently, but using multiple products that are widely available. Future research on college populations needs to continue focus on how alternative tobacco use is changing beliefs and attitudes associated with use. By addressing use of alternative and new-to-market products, there is potential for declines in use to continue to Fall among students.

List of References

1. U.S. Department of Health and Human Services. The Health Consequences of Smoking—50 Years of Progress: A Report of the Surgeon General. 2014.
2. Eriksen MM, J; Schluger, N; Islami, F; Drope, J;. *The Tobacco Atlas: 5th Edition.* 2015.
3. U.S. Department of Health and Human Services (USDHHS). The 2004 United States Surgeon General's Report: The Health Consequences of Smoking. *New South Wales Public Health Bulletin.* 2004;15(5-6):107-107.
4. Goodwin RD, Grinberg A, Shapiro J, et al. Hookah use among college students: prevalence, drug use, and mental health. *Drug and alcohol dependence.* 2014;141(0):16-20.
5. Jha P, Ramasundarahettige C, Landsman V, et al. 21st-century hazards of smoking and benefits of cessation in the United States. *N Engl J Med.* 2013;368(4):341-350.
6. Arrazola RAS, T; Corey, C.G.; Husten, C.G.; Neff, L.J.; Apelberg, B.J.; Bunnell, R.E.; Choiniere, C.J.; King, B.A.; Cox, S; McAfee, T; Caraballo, R.S.;. *Tobacco Use Among Middle and High School Students — United States, 2011–2014.* April 17, 2015 2015.
7. U.S. Department of Health and Human Services. *Preventing Tobacco Use Among Youth and Young Adults: A Report of the Surgeon General.* Atlanta, GA2012.
8. Prokhorov AV, Warneke C, de Moor C, et al. Self-reported health status, health vulnerability, and smoking behavior in college students: implications for intervention.

Nicotine & tobacco research : official journal of the Society for Research on Nicotine and Tobacco. 2003;5(4):545-552.

9. Murphy-Hoefer R, Griffith R, Pederson LL, Crossett L, Iyer SR, Hiller MD. A review of interventions to reduce tobacco use in colleges and universities. *American journal of preventive medicine.* 2005;28(2):188-200.

10. American Non-Smokers Rights Foundation (ANRF). *U.S. Colleges and Universities with Smokefree Air Policie.* American Non-Smokers Rights Foundation;2016.

11. Johnston LD, O'Malley PM, Bachman JG, Schulenberg JE, Miech RA. *Monitoring the Future national survey results on drug use, 1975-2015: Volume II, college students and adults ages 19-55.* Ann Arbor, MI Institute for Social Research: The University of Michigan;2016.

12. Johnston LD, O'Malley PM, Bachman JG. *Monitoring the Future National Survey Results on Drug Use, 1975-2012. Volume II: College Students & Adults Ages 19-40, 2013.* 2014.

13. Berg CJ, Stratton E, Schauer GL, et al. Perceived harm, addictiveness, and social acceptability of tobacco products and marijuana among young adults: marijuana, hookah, and electronic cigarettes win. *Subst Use Misuse.* 2015;50(1):79-89.

14. Leventhal AM, Strong DR, Kirkpatrick MG, et al. Association of electronic cigarette use with initiation of combustible tobacco product smoking in early adolescence. *Jama.* 2015;314(7):700-707.

15. Doran N, Godfrey KM, Myers MG. Hookah use predicts cigarette smoking progression among college smokers. *Nicotine & Tobacco Research.* 2015:ntu343.

16. Everett SA, Husten CG, Kann L, Warren CW, Sharp D, Crossett L. Smoking initiation and smoking patterns among US college students. *Journal Of American College Health: J Of ACH.* 1999;48(2):55-60.

17. Wetter DW, Kenford SL, Welsch SK, et al. Prevalence and predictors of transitions in smoking behavior among college students. *Health psychology : official journal of the Division of Health Psychology, American Psychological Association.* 2004;23(2):168-177.

18. Halperin AC, Smith SS, Heiligenstein E, Brown D, Fleming MF. Cigarette smoking and associated health risks among students at five universities. *Nicotine & tobacco research : official journal of the Society for Research on Nicotine and Tobacco.* 2010;12(2):96-104.

19. Primack BA, Land SR, Fan J, Kim KH, Rosen D. Associations of mental health problems with waterpipe tobacco and cigarette smoking among college students. *Subst Use Misuse.* 2013;48(3):211-219.

20. Caldeira KM, O'Grady KE, Garnier-Dykstra LM, Vincent KB, Pickworth WB, Arria AM. Cigarette smoking among college students: longitudinal trajectories and health outcomes. *Nicotine & tobacco research : official journal of the Society for Research on Nicotine and Tobacco.* 2012;14(7):777-785.

21. Meier EM, Tackett AP, Miller MB, Grant DM, Wagener TL. Which Nicotine Products Are Gateways to Regular Use?: First-Tried Tobacco and Current Use in College Students. *American journal of preventive medicine.* 2015;48(1, Supplement 1):S86-S93.

22. Sutfin EL, Sparks A, Pockey JR, et al. First tobacco product tried: Associations with smoking status and demographics among college students. *Addictive behaviors.* 2015;51:152-157.

23. Haardörfer R, Berg CJ, Lewis M, et al. Polytobacco, marijuana, and alcohol use patterns in college students: A latent class analysis. *Addictive behaviors.* 2016;59:58-64.

24. Tran A, Nehl EJ, Sales J, Berg CJ. Problem Drinking Behaviors: Differential Effects of Stress and School Type on College Students. *Open J Prev Med.* 2014;4(4):216-221.

25. Kanny D, Liu Y, Brewer RD, Lu H. Binge drinking—United States, 2011. *Morbidity and mortality weekly report Surveillance summaries.* 2013;62(Suppl 3):77-80.

26. Lee YO, Hebert CJ, Nonnemaker JM, Kim AE. Multiple tobacco product use among adults in the United States: Cigarettes, cigars, electronic cigarettes, hookah, smokeless tobacco, and snus. *Preventive Medicine.* 2014;62:14-19.

27. Post A, Gilljam H, Rosendahl I, Bremberg S, Rosaria Galanti M. Symptoms of nicotine dependence in a cohort of Swedish youths: a comparison between smokers, smokeless tobacco users and dual tobacco users. *Addiction (Abingdon, England).* 2010;105(4):740-746.

28. Latimer LA, Batanova M, Loukas A. Prevalence and harm perceptions of various tobacco products among college students. *Nicotine & tobacco research : official journal of the Society for Research on Nicotine and Tobacco.* 2014;16(5):519-526.

29. Butler KM, Ickes MJ, Rayens MK, Wiggins AT, Hahn EJ. Polytobacco Use Among College Students. *Nicotine & Tobacco Research.* 2016;18(2):163-169.

30. Sutfin EL, McCoy TP, Berg CJ, et al. Tobacco Use by College Students: A Comparison of Daily and Nondaily Smokers. *American journal of health behavior.* 2012;36(2):218-229.

31. Shishani K, Howell D, McPherson S, Roll J. Young adult waterpipe smokers: Smoking behaviors and associated subjective and physiological effects. *Addictive behaviors.* 2014;39(6):1113-1119.

32. Moran S, Wechsler H, Rigotti NA. Social Smoking Among US College Students. *Pediatrics.* 2004;114(4):1028-1034.

33. Levinson AH, Campo S, Gascoigne J, Jolly O, Zakharyan A, Tran Z. Smoking, but not smokers: identity among college students who smoke cigarettes. *Nicotine & Tobacco Research: Official Journal Of The Society For Research On Nicotine And Tobacco.* 2007;9(8):845-852.

34. Allen AM, Scheuermann TS, Nollen N, Hatsukami D, Ahluwalia JS. Gender Differences in Smoking Behavior and Dependence Motives Among Daily and Nondaily Smokers. *Nicotine & tobacco research : official journal of the Society for Research on Nicotine and Tobacco.* 2016;18(6):1408-1413.

35. Grekin ER, Ayna D. Waterpipe smoking among college students in the United States: a review of the literature. *Journal of American college health : J of ACH.* 2012;60(3):244-249.

36. Flay BS, F; Petraitis, J;. *The theory of triadic influence. In: DiClemente RJ, Kegler MC, Crosby RA,. Emerging theories in health promotion practice and research.* 2nd ed. New York: Jossey-Bass; 2009.

37. FitzGerald EA, Frasso R, Dean LT, Johnson TE, Solomon S, Bugos E. Community-Generated Recommendations Regarding the Urban Nutrition and Tobacco Environments: A Photo-Elicitation Study in Philadelphia. *Preventing Chronic Disease.* 2013;10:E98.

38. McLeroy KR, Bibeau D, Steckler A, Glanz K. An Ecological Perspective on Health Promotion Programs. *Health Education & Behavior.* 1988;15(4):351-377.

39. Wagoner KG, Song EY, Egan KL, et al. E-cigarette Availability and Promotion Among Retail Outlets Near College Campuses in Two Southeastern States. *Nicotine & Tobacco Research.* 2014;16(8):1150-1155.

40. Sung HY, Wang Y, Yao T, Lightwood J, Max W. Polytobacco Use of Cigarettes, Cigars, Chewing Tobacco, and Snuff Among US Adults. *Nicotine & tobacco research : official journal of the Society for Research on Nicotine and Tobacco.* 2016;18(5):817-826.

41. Agaku IK, BA ; Dube, SR;. *Current Cigarette Smoking Among Adults — United States, 2005–2012.* Centers for Disease Control and Prevention;2014.

42. Sterling K, Berg CJ, Thomas AN, Glantz SA, Ahluwalia JS. Factors associated with small cigar use among college students. *American journal of health behavior.* 2013;37(3):325-333.

43. Cohn A, Villanti A, Richardson A, et al. The association between alcohol, marijuana use, and new and emerging tobacco products in a young adult population. *Addictive behaviors.* 2015;48:79-88.

44. Primack BA, Shensa A, Kim KH, et al. Waterpipe smoking among U.S. university students. *Nicotine & tobacco research : official journal of the Society for Research on Nicotine and Tobacco.* 2013;15(1):29-35.

45. Primack BA, Mah J, Shensa A, Rosen D, Yonas MA, Fine MJ. Associations between race, ethnicity, religion, and waterpipe tobacco smoking. *Journal of ethnicity in substance abuse.* 2014;13(1):58-71.

46. Jarrett T, Blosnich J, Tworek C, Horn K. Hookah Use Among U.S. College Students: Results From the National College Health Assessment II. *Nicotine Tob Res.* 2012;14(10):1145-1153.

47. El-Zaatari ZM, Chami HA, Zaatari GS. Health effects associated with waterpipe smoking. *Tobacco control.* 2015:tobaccocontrol-2014-051908.

48. Braun RE, Glassman T, Wohlwend J, Whewell A, Reindl DM. Hookah use among college students from a Midwest University. *Journal of community health.* 2012;37(2):294-298.

49. Hopfer C. Implications of Marijuana Legalization for Adolescent Substance Use. *Substance Abuse.* 2014;35(4):331-335.

50. Schauer GL, King BA, Bunnell RE, Promoff G, McAfee TA. Toking, Vaping, and Eating for Health or Fun: Marijuana Use Patterns in Adults, U.S., 2014. *American journal of preventive medicine.* 2015.

51. Morean ME, Kong G, Camenga DR, Cavallo DA, Krishnan-Sarin S. High School Students' Use of Electronic Cigarettes to Vaporize Cannabis. *Pediatrics.* 2015.

52. Volkow ND, Baler RD, Compton WM, Weiss SRB. Adverse Health Effects of Marijuana Use. *New England Journal of Medicine.* 2014;370(23):2219-2227.

53. Evans-Polce R, Lanza S, Maggs J. Heterogeneity of alcohol, tobacco, and other substance use behaviors in U.S. college students: A latent class analysis. *Addictive behaviors.* 2016;53:80-85.

54. Wechsler H, Nelson TF. What we have learned from the Harvard School of Public Health College Alcohol Study: Focusing attention on college student alcohol consumption and

the environmental conditions that promote it. *Journal of studies on alcohol and drugs.* 2008;69(4):481-490.

55. Sterling K, Berg CJ, Thomas AN, Glantz SA, Ahluwalia JS. Factors associated with small cigar use among college students. *American journal of health behavior.* 2013;37(3):325.

56. Littlefield AK, Gottlieb JC, Cohen LM, Trotter DR. Electronic Cigarette Use Among College Students: Links to Gender, Race/Ethnicity, Smoking, and Heavy Drinking. *Journal of American college health : J of ACH.* 2015;63(8):523-529.

57. Jorenby DE, Smith SS, Fiore MC, Baker TB. Nicotine levels, withdrawal symptoms, and smoking reduction success in real world use: A comparison of cigarette smokers and dual users of both cigarettes and E-cigarettes. *Drug and alcohol dependence.* 2016;170:93-101.

58. White A, Hingson R. The burden of alcohol use: excessive alcohol consumption and related consequences among college students. *Alcohol research : current reviews.* 2013;35(2):201.

59. Fielder RL, Carey KB, Carey MP. Prevalence, frequency, and initiation of hookah tobacco smoking among first-year female college students: a one-year longitudinal study. *Addictive behaviors.* 2012;37(2):221-224.

60. Suerken CK, Reboussin BA, Sutfin EL, Wagoner KG, Spangler J, Wolfson M. Prevalence of marijuana use at college entry and risk factors for initiation during freshman year. *Addictive behaviors.* 2014;39(1):302-307.

61. Walitzer KS, Dearing RL. Characteristics of alcoholic smokers, nonsmokers, and former smokers: personality, negative affect, alcohol involvement, and treatment participation. *Nicotine & Tobacco Research.* 2013;15(1):282-286.

62. Palmer RS, McMahon TJ, Moreggi DI, Rounsaville BJ, Ball SA. College Student Drug Use: Patterns, Concerns, Consequences, and Interest in Intervention. *Journal of College Student Development.* 2012;53(1):124-132.

63. Barrett SP, Darredeau C, Pihl RO. Patterns of simultaneous polysubstance use in drug using university students. *Human Psychopharmacology: Clinical and Experimental.* 2006;21(4):255-263.

64. Sutfin EL, McCoy TP, Reboussin BA, Wagoner KG, Spangler J, Wolfson M. Prevalence and correlates of waterpipe tobacco smoking by college students in North Carolina. *Drug and alcohol dependence.* 2011;115(1-2):131-136.

65. Borsari B, Carey KB. Peer influences on college drinking: A review of the research. *Journal of substance abuse.* 2001;13(4):391-424.

66. Noland M, Ickes MJ, Rayens MK, Butler K, Wiggins AT, Hahn EJ. Social influences on use of cigarettes, e-cigarettes, and hookah by college students. *Journal of American College Health.* 2016;64(4):319-328.

67. Berg CJ, Parelkar PP, Lessard L, et al. Defining "smoker": college student attitudes and related smoking characteristics. *Nicotine & tobacco research : official journal of the Society for Research on Nicotine and Tobacco.* 2010;12(9):963-969.

68. Berg CJ, Lust KA, Sanem JR, et al. Smoker self-identification versus recent smoking among college students. *American journal of preventive medicine.* 2009;36(4):333-336.

69. American College Health Association. *ACHA-NCHA Frequently Asked Questions.* 2014.

70. American College Health Association. About ACHA-NCHA Generalizability, Reliability, and Validity Analysis. 2012; http://www.acha-ncha.org/grvanalysis.html. Accessed December, 2012.

71. Hoeppner BB, Bidwell LC, Colby SM, Barnett NP. Smoking patterns and their relationship to drinking among first-year college students. *Nicotine & tobacco research : official journal of the Society for Research on Nicotine and Tobacco.* 2014;16(6):743-752.

72. Hoeppner BB, Barnett NP, Jackson KM, et al. Daily college student drinking patterns across the first year of college. *Journal of studies on alcohol and drugs.* 2012;73(4):613-624.

73. Abdi H. Bonferroni and Šidák corrections for multiple comparisons. *Encyclopedia of measurement and statistics.* 2007;3:103-107.

74. Yu ES, Saddleson ML, Murphy JM, Giovino GA, Mahoney MC. Patterns of Polytobacco Use among College Students. *Health Behavior and Policy Review.* 2017;4(2):173-181.

75. Tomar SL, Alpert HR, Connolly GN. Patterns of dual use of cigarettes and smokeless tobacco among US males: findings from national surveys. *Tob Control.* 2010;19(2):104-109.

76. Sidani JE, Shensa A, Primack BA. Substance and hookah use and living arrangement among fraternity and sorority members at US colleges and universities. *Journal of community health.* 2013;38(2):238-245.

77. Berg CJ, Sutfin EL, Mendel J, Ahluwalia JS. Use of and interest in smoking cessation strategies among daily and nondaily college student smokers. *Journal of American college health : J of ACH.* 2012;60(3):194-202.

78. Rodgers KC. A review of multicomponent interventions to prevent and control tobacco use among college students. *Journal of American College Health.* 2012;60(3):257-261.

79. Spangler J, Song E, Pockey J, et al. Correlates of smokeless tobacco use among first year college students. *Health education journal.* 2014;73(6):693-701.

80. Kenney SR, LaBrie JW, Lac A. Injunctive Peer Misperceptions and the Mediation of Self-Approval on Risk for Driving After Drinking Among College Students. *Journal of health communication.* 2013;18(4):459-477.

81. Nichter M, Nichter M, Carkoglu A, Lloyd-Richardson E, Tobacco Etiology Research N. Smoking and drinking among college students: "it's a package deal". *Drug and alcohol dependence.* 2010;106(1):16-20.

82. Kilmer JR, Walker DD, Lee CM, et al. Misperceptions of college student marijuana use: Implications for prevention. *J Stud Alcohol.* 2006;67(2):277-281.

83. Perkins HW, Haines MP, Rice R. Misperceiving the college drinking norm and related problems: a nationwide study of exposure to prevention information, perceived norms and student alcohol misuse. *J Stud Alcohol.* 2005;66(4):470-478.

84. Perkins HW, Meilman PW, Leichliter JS, Cashin JR, Presley CA. Misperceptions of the norms for the frequency of alcohol and other drug use on college campuses. *Journal of American College Health.* 1999;47(6):253-258.

85. Terry CP, Terry DL. Exaggeration of perceived smoking norms among college students: Does smoking status matter? *Addiction Research & Theory.* 2012;20(4):291-299.

86. Heinz AJ, Giedgowd GE, Crane NA, et al. A comprehensive examination of hookah smoking in college students: use patterns and contexts, social norms and attitudes, harm

perception, psychological correlates and co-occurring substance use. *Addictive behaviors.* 2013;38(11):2751-2760.

87. Cooke ME, Nasim A, Cho SB, Kendler KS, Clark SL, Dick DM. Predicting Tobacco Use across the First Year of College. *American journal of health behavior.* 2016;40(4):484-495.

88. National Center for Education Statistics. *Total fall enrollment in degree-granting postsecondary institutions, by attendance status, sex of student, and control of institution: Selected years, 1947 through 2024.* 2015.

89. Berg CJ, Lowe K, Stratton E, et al. Sociodemographic, Psychosocial, and Health Behavior Risk Factors Associated with Sexual Risk Behaviors among Southeastern US College Students. *Open J Prev Med.* 2014;4(6):387-395.

90. Mohler-Kuo M, Lee JE, Wechsler H. Trends in marijuana and other illicit drug use among college students: Results from 4 Harvard School of Public Health College Alcohol Study surveys: 1993-2001. *Journal of American College Health.* 2003;52(1):17-24.

91. Hingson RW, Zha W, Weitzman ER. Magnitude of and trends in alcohol-related mortality and morbidity among U.S. college students ages 18-24, 1998-2005. *Journal of studies on alcohol and drugs Supplement.* 2009(16):12.

92. McCambridge J, Hunt C, Jenkins RJ, Strang J. Cluster randomised trial of the effectiveness of motivational interviewing for universal prevention. *Drug and alcohol dependence.* 2011;114(2):177-184.

93. Sloboda Z, Stephens RC, Stephens PC, et al. The Adolescent Substance Abuse Prevention Study: A randomized field trial of a universal substance abuse prevention program. *Drug and alcohol dependence.* 2009;102(1):1-10.

94. Ribisl KM, D'Angelo H, Evenson KR, Fleischhacker S, Myers AE, Rose SW. Integrating Tobacco Control and Obesity Prevention Initiatives at Retail Outlets. *Preventing Chronic Disease.* 2016;13:E35.

95. Mukamal KJ. The effects of smoking and drinking on cardiovascular disease and risk factors. *Alcohol Research and Health.* 2006;29(3):199.

96. Belsky DW, Moffitt TE, Baker TB, et al. Polygenic risk and the developmental progression to heavy, persistent smoking and nicotine dependence: Evidence from a 4-decade longitudinal study. *JAMA Psychiatry.* 2013;70(5):534-542.

97. Ramo DE, Liu H, Prochaska JJ. Tobacco and marijuana use among adolescents and young adults: A systematic review of their co-use. *Clinical Psychology Review.* 2012;32(2):105-121.

98. Primack BA, Kim KH, Shensa A, Sidani JE, Barnett TE, Switzer GE. Tobacco, marijuana, and alcohol use in university students: a cluster analysis. *Journal of American college health : J of ACH.* 2012;60(5):374-386.

99. Dierker L, Stolar M, Lloyd-Richardson E, et al. Tobacco, Alcohol, and Marijuana Use Among First-Year U.S. College Students: A Time Series Analysis. *Substance Use & Misuse, 2008, Vol43(5), p680-699.* 2008;43(5):680-699.

100. Berg CJ, Buchanan TS, Grimsley L, Rodd J, Smith D. Personality characteristics and health risk behaviors associated with current marijuana use among college students. *Open Journal of Preventive Medicine.* 2011;01(03):101.

101. Witkiewitz K, Desai SA, Steckler G, et al. Concurrent drinking and smoking among college students: An event-level analysis. *Psychology of addictive behaviors : journal of the Society of Psychologists in Addictive Behaviors.* 2012;26(3):649-654.

102. Primack BA, Sidani J, Agarwal AA, Shadel WG, Donny EC, Eissenberg TE. Prevalence of and associations with waterpipe tobacco smoking among U.S. university students. *Annals of behavioral medicine : a publication of the Society of Behavioral Medicine.* 2008;36(1):81-86.

103. Carter CA, Kahnweiler WM. The efficacy of the social norms approach to substance abuse prevention applied to fraternity men. *Journal of American College Health.* 2000;49(2):66-71.

104. Ramo DE, Young-Wolff KC, Prochaska JJ. Prevalence and correlates of electronic-cigarette use in young adults: findings from three studies over five years. *Addictive behaviors.* 2015;41(0):142-147.

105. Nuzzo E, Shensa A, Kim KH, et al. Associations between hookah tobacco smoking knowledge and hookah smoking behavior among US college students. *Health education research.* 2013;28(1):92-100.

106. Sterling K, Berg CJ, Thomas AN, Glantz SA, Ahluwalia JS. Factors associated with small cigar use among college students. *American journal of health behavior.* 2013;37(3):325-333.

107. Enofe N, Berg CJ, Nehl EJ. Alternative Tobacco Use among College Students: Who is at Highest Risk? *American journal of health behavior.* 2014;38(2):180-189.

108. Schane RE, Glantz SA, Ling PM. Nondaily and social smoking: An increasingly prevalent pattern. *Archives of Internal Medicine.* 2009;169(19):1742-1744.

109. Wechsler H, Davenport AE, Dowdall GW, Grossman SJ, Zanakos SI. Binge drinking, tobacco, and illicit drug use and involvement in college athletics. A survey of students at

140 American colleges. *Journal of American college health : J of ACH.* 1997;45(5):195-200.

110. Wechsler H, Davenport A, Dowdall G, Moeykens B, Castillo S. Health and behavioral consequences of binge drinking in college: A national survey of students at 140 campuses. *Jama.* 1994;272(21):1672-1677.

111. Berg CJ. Reasons for Nondaily Smoking among Young Adults: Scale Development and Validation. *Journal of smoking cessation.* 2014;9(1):17-25.

112. Schane RE, Ling PM, Glantz SA. Health effects of light and intermittent smoking: a review. *Circulation.* 2010;121(13):1518-1522.

113. Brown AE, Carpenter MJ, Sutfin EL. Occasional smoking in college: who, what, when and why? *Addictive behaviors.* 2011;36(12):1199-1204.

114. Primack BA, Soneji S, Stoolmiller M, Fine MJ, Sargent JD. Progression to Traditional Cigarette Smoking After Electronic Cigarette Use Among US Adolescents and Young Adults. *JAMA Pediatr.* 2015;169(11):1018-1023.

115. Sutfin EL, McCoy TP, Morrell HE, Hoeppner BB, Wolfson M. Electronic cigarette use by college students. *Drug and alcohol dependence.* 2013;131(3):214-221.

116. Fielder RL, Carey KB, Carey MP. Hookah, cigarette, and marijuana use: A prospective study of smoking behaviors among first-year college women. *Addictive behaviors.* 2013;38(11):2729-2735.

117. White HR, Morgan TJ, Pugh LA, Celinska K, Labouvie EW, Pandina RJ. Evaluating two brief substance-use interventions for mandated college students. *J Stud Alcohol.* 2006;67(2):309-317.

118. Dennhardt AA, Murphy JG. Prevention and treatment of college student drug use: A review of the literature. *Addictive behaviors.* 2013;38(10):2607-2618.

119. Erickson DJ, Lenk KM, Forster JL. Latent classes of young adults based on use of multiple types of tobacco and nicotine products. *Nicotine & tobacco research : official journal of the Society for Research on Nicotine and Tobacco.* 2014;16(8):1056-1062.

120. Weitzman ER, Nelson TF, Wechsler H. Taking up binge drinking in college: the influences of person, social group, and environment. *The Journal of adolescent health : official publication of the Society for Adolescent Medicine.* 2003;32(1):26-35.

121. American College Health Association. *National College Health Assessment, Spring 2014 Exectuve Summary.* 2014.

122. Sutfin EL, Reboussin BA, McCoy TP, Wolfson M. Are college student smokers really a homogeneous group? a latent class analysis of college student smokers. *Nicotine & tobacco research : official journal of the Society for Research on Nicotine and Tobacco.* 2009;11(4):444-454.

123. Sutfin EL, Song EY, Reboussin BA, Wolfson M. What are young adults smoking in their hookahs? A latent class analysis of substances smoked. *Addictive behaviors.* 2014;39(7):1191-1196.

124. Nylund KL, Asparouhov T, Muthén BO. Deciding on the number of classes in latent class analysis and growth mixture modeling: A Monte Carlo simulation study. *Structural equation modeling.* 2007;14(4):535-569.

125. Asparouhov T, Muthén B. Using Mplus TECH11 and TECH14 to test the number of latent classes. *Mplus Web Notes.* 2012;14:22.

126. Magidson J, Vermunt JK. Latent class models. *The Sage handbook of quantitative methodology for the social sciences.* 2004:175-198.

127. Bacher JW, K. Vogler, M.;. *SPSS TwoStep Cluster: A First Evaluation.* Belmont, MA2004.

128. Kent P, Jensen RK, Kongsted A. A comparison of three clustering methods for finding subgroups in MRI, SMS or clinical data: SPSS TwoStep Cluster analysis, Latent Gold and SNOB. *BMC medical research methodology.* 2014;14:113.

129. Haughton D, Legrand P, Woolford S. Review of Three Latent Class Cluster Analysis Packages: Latent Gold, poLCA, and MCLUST. *The American Statistician.* 2009;63(1):81-91.

130. Prendergast ML. Substance Use and Abuse among College-Students - a Review of Recent Literature. *Journal of American College Health.* 1994;43(3):99-113.

131. Harris KJ, Stearns JN, Kovach RG, Harrar SW. Enforcing an outdoor smoking ban on a college campus: effects of a multicomponent approach. *Journal of American College Health.* 2009;58(2):121-126.

132. Carey KB, Scott-Sheldon LA, Garey L, Elliott JC, Carey MP. Alcohol interventions for mandated college students: A meta-analytic review. 2016.

133. Small M, Bailey-Davis L, Morgan N, Maggs J. Changes in eating and physical activity behaviors across seven semesters of college: living on or off campus matters. *Health Education & Behavior.* 2013;40(4):435-441.

134. Porter SR. Do college student surveys have any validity? *The Review of Higher Education.* 2011;35(1):45-76.

135. Blanco C, Okuda M, Wright C, et al. Mental health of college students and their non–college-attending peers: results from the national epidemiologic study on alcohol and related conditions. *Archives of general psychiatry.* 2008;65(12):1429-1437.

136. Gfroerer JC, Greenblatt JC, Wright DA. Substance use in the US college-age population: differences according to educational status and living arrangement. *American journal of public health.* 1997;87(1):62-65.

137. Cantrell J, Pearson JL, Anesetti-Rothermel A, Xiao H, Kirchner TR, Vallone D. Tobacco Retail Outlet Density and Young Adult Tobacco Initiation. *Nicotine & Tobacco Research.* 2016;18(2):130-137.

138. Chan WC, Leatherdale ST. Tobacco retailer density surrounding schools and youth smoking behaviour: a multi-level analysis. *Tob Induc Dis.* 2011;9(1):9.

139. Pulakka A, Halonen JI, Kawachi I, et al. Association between distance from home to tobacco outlet and smoking cessation and relapse. *JAMA Intern Med.* 2016.

140. Halonen JI, Kivimäki M, Kouvonen A, et al. Proximity to a tobacco store and smoking cessation: a cohort study. *Tobacco control.* 2013:tobaccocontrol-2012-050726.

141. World Health Organization. *WHO Report on the Global Tobacco Epidemic, 2013: Enforcing Bans on Tobacco Advertising, Promotion and Sponsorship.* Geneva, Switzerland: World Health Organization2013.

142. Campaign for Tobacco Free Kids. *DEADLY ALLIANCE: How Big Tobacco and Convenience Stores Partner to Market Tobacco Products and Fight Life-Saving Policies.* June 14, 2016 2012.

143. Reitzel LR, Cromley EK, Li Y, et al. The effect of tobacco outlet density and proximity on smoking cessation. *American Journal of Public Health.* 2011;101(2):315-320.

144. Ackerman A, Etow A, Bartel S, Ribisl KM. Reducing the density and number of tobacco retailers: Policy solutions and legal issues. *Nicotine & Tobacco Research.* 2016.

145. Henriksen L. Comprehensive tobacco marketing restrictions: promotion, packaging, price and place. *Tobacco Control.* 2012;21(2):147-153.

146. Peterson NA, Lowe JB, Reid RJ. Tobacco Outlet Density, Cigarette Smoking Prevalence, and Demographics at the County Level of Analysis. *Substance Use & Misuse.* 2005;40(11):1627-1635.

147. Reid RJ, Peterson NA, Lowe JB, Hughey J. Tobacco outlet density and smoking prevalence: Does racial concentration matter. *Drugs: Education, Prevention, and Policy, 2005, Vol12(3), p233-238.* 2005;12(3):233-238.

148. D'Angelo H, Ammerman A, Gordon-Larsen P, Linnan L, Lytle L, Ribisl KM. Sociodemographic Disparities in Proximity of Schools to Tobacco Outlets and Fast-Food Restaurants. *American Journal of Public Health.* 2016;106(9):1556-1562.

149. Rodriguez D, Carlos HA, Adachi-Mejia AM, Berke EM, Sargent JD. Predictors of tobacco outlet density nationwide: a geographic analysis. *Tobacco control.* 2012:tobaccocontrol-2011-050120.

150. Lantz PM, Jacobson PD, Warner KE, et al. Investing in youth tobacco control: a review of smoking prevention and control strategies. *Tobacco Control.* 2000;9(1):47-63.

151. Novak SP, Reardon SF, Raudenbush SW, Buka SL. Retail tobacco outlet density and youth cigarette smoking: a propensity-modeling approach. *Am J Public Health.* 2006;96(4):670-676.

152. Patterson F, Lerman C, Kaufmann VG, Neuner GA, Audrain-McGovern J. Cigarette smoking practices among American college students: review and future directions. *Journal of American College Health.* 2004;52(5):203-210.

153. Xu X, Bishop EE, Kennedy SM, Simpson SA, Pechacek TF. Annual healthcare spending attributable to cigarette smoking: an update. *American journal of preventive medicine.* 2015;48(3):326-333.

154. Loomis BR, Kim AE, Goetz JL, Juster HR. Density of tobacco retailers and its association with sociodemographic characteristics of communities across New York. *Public Health.* 2013;127(4):333-338.

155. Lipperman-Kreda S, Grube JW, Friend KB. Local Tobacco Policy and Tobacco Outlet Density: Associations With Youth Smoking. *Journal of Adolescent Health.* 2012;50(6):547-552.

156. Lee YO, Bahreinifar S, Ling PM. Understanding Tobacco-Related Attitudes Among College and Noncollege Young Adult Hookah and Cigarette Users. *Journal of American College Health.* 2013;62(1):10-18.

157. Hahn EJ, Begley K, Gokun Y, Johnson AO, Mundy ME, Rayens MK. Electronic Cigarette Retail Outlets and Proximity to Schools. *American Journal of Health Promotion.* 2014.

158. Leatherdale S, Strath J. Tobacco retailer density surrounding schools and cigarette access behaviors among underage smoking students. *ann behav med.* 2007;33(1):105-111.

159. Yu D, Peterson NA, Sheffer MA, Reid RJ, Schnieder JE. Tobacco outlet density and demographics: Analysing the relationships with a spatial regression approach. *Public Health.* 2010;124(7):412-416.

160. Meng G, Brown KS, Thompson ME. Spatial and temporal patterns of smoking prevalence in Ontario. *BMC Public Health.* 2015;15(1):1-13.

161. Chuang Y-C, Cubbin C, Ahn D, Winkleby MA. Effects of neighbourhood socioeconomic status and convenience store concentration on individual level smoking. *Journal of Epidemiology and Community Health.* 2005;59(7):568-573.

162. Henriksen L, Feighery EC, Schleicher NC, Cowling DW, Kline RS, Fortmann SP. Is adolescent smoking related to the density and proximity of tobacco outlets and retail cigarette advertising near schools? *Preventive Medicine.* 2008;47(2):210-214.

163. Hiscock R, Bauld L, Amos A, Fidler JA, Munafò M. Socioeconomic status and smoking: a review. *Annals of the New York Academy of Sciences.* 2012;1248(1):107-123.

164. Siahpush M, Jones PR, Singh GK, Timsina LR, Martin J. Association of availability of tobacco products with socio-economic and racial/ethnic characteristics of neighbourhoods. *Public Health.* 2010;124(9):525-529.

165. Rose SW, Barker DC, D'Angelo H, et al. The availability of electronic cigarettes in US retail outlets, 2012: results of two national studies. *Tobacco Control.* 2014;23(suppl 3):iii10-iii16.

166. Virginia Department of Taxation. Tobacco Products Tax. 2016; http://www.tax.virginia.gov/content/tobacco-products-tax. Accessed June 14, 2016.

167. Trumbo CW, Harper R. Perceived Characteristics of E-cigarettes as an Innovation by Young Adults. *Health Behavior and Policy Review.* 2015;2(2):154-162.

168. Ayers JW, Althouse BM, Allem J-P, Leas EC, Dredze M, Williams RS. Revisiting the Rise of Electronic Nicotine Delivery Systems Using Search Query Surveillance. *American journal of preventive medicine.* 2016;50(6):e173-e181.

169. Ayers JW, Ribisl KM, Brownstein JS. Tracking the Rise in Popularity of Electronic Nicotine Delivery Systems (Electronic Cigarettes) Using Search Query Surveillance. *American journal of preventive medicine.* 2011;40(4):448-453.

170. Virginia Economic Commuinity Partnership. *Community Profile: Richmond MSA, Virginia.*

171. Bureau USC. *Annual Estimates of the Resident Population: April 1, 2010 to July 1, 2014 - United States -- Metropolitan and Micropolitan Statistical Area; and for Puerto Rico* 2016.

172. Richardson A, Ganz O, Vallone D. Tobacco on the web: surveillance and characterisation of online tobacco and e-cigarette advertising. *Tobacco Control.* 2015;24(4):341-347.

173. Zhu S-H, Sun JY, Bonnevie E, et al. Four hundred and sixty brands of e-cigarettes and counting: implications for product regulation. *Tobacco Control.* 2014;23(suppl 3):iii3-iii9.

174. Singh T. Characteristics of Electronic Cigarette Use Among Middle and High School Students—United States, 2015. *MMWR Morbidity and Mortality Weekly Report.* 2016;65.

175. Bureau USC. *2015 TIGER/Line Shapefiles (machine readable data files).* 2015.

176. *ArcGIS Release 10.4.1* [computer program]. Redlands, CA2016.

177. Hyland A, Travers MJ, Cummings KM, Bauer J, Alford T, Wieczorek WF. Tobacco outlet density and demographics in Erie County, New York. *Am J Public Health.* 2003;93.

178. Agency for Healthcare Research and Quality. Creation of New Race-Ethnicity Codes and Socioeconomic Status (SES) Indicators for MEdicare Beneficiarie. 2008;

http://archive.ahrq.gov/research/findings/final-reports/medicareindicators/medicareindicators3a.html. Accessed June 16, 2016.

179. Krieger N, Chen JT, Waterman PD, Rehkopf DH, Subramanian SV. Painting a truer picture of US socioeconomic and racial/ethnic health inequalities: the Public Health Disparities Geocoding Project. *Am J Public Health.* 2005;95(2):312-323.

180. Franco M, Diez Roux AV, Glass TA, Caballero B, Brancati FL. Neighborhood Characteristics and Availability of Healthy Foods in Baltimore. *American journal of preventive medicine.* 2008;35(6):561-567.

181. Moore LV, Diez Roux AV. Associations of neighborhood characteristics with the location and type of food stores. *Am J Public Health.* 2006;96(2):325-331.

182. Timperio A, Ball K, Salmon J, et al. Personal, Family, Social, and Environmental Correlates of Active Commuting to School. *American journal of preventive medicine.* 2006;30(1):45-51.

183. DiGuiseppi C, Roberts I, Li L, Allen D. Determinants of car travel on daily journeys to school: cross sectional survey of primary school children. *BMJ.* 1998;316(7142):1426-1428.

184. Bureau UC. Geographic Terms and Concepts - Census Tract. https://www.census.gov/geo/reference/gtc/gtc_ct.html. Accessed November, 2016.

185. Duncan DT, Kawachi I, Melly SJ, Blossom J, Sorensen G, Williams DR. Demographic Disparities in the Tobacco Retail Environment in Boston: A Citywide Spatial Analysis. *Public Health Reports.* 2014;129(2):209-215.

186. Dai H, Hao J. Geographic density and proximity of vape shops to colleges in the USA. *Tobacco Control.* 2016.

187. Diez-Roux A, Nieto F, Muntaner C, et al. Neighborhood environments and coronary heart disease: a multilevel analysis. *Am J Epidemiol.* 1997;146(1):48 - 63.

188. Diez-Roux A, Kiefe C, Jacobs D, et al. Area characteristics and individual-level socioeconomic position indicators in three population-based epidemiologic studies. *Ann Epidemiol.* 2001;11(6):395 - 405.

189. Rodriguez D, Carlos HA, Adachi-Mejia AM, Berke EM, Sargent J. Retail tobacco exposure: Using geographic analysis to identify areas with excessively high retail density. *nicotine & tobacco research.* 2014;16(2):155-165.

190. Ribisl KM, Luke DA, Bohannon DL, Sorg AA, Moreland-Russell S. Reducing Disparities in Tobacco Retailer Density by Banning Tobacco Product Sales Near Schools. *Nicotine & Tobacco Research.* 2016;19(2):239-244.

191. Widome R, Brock B, Noble P, Forster JL. The relationship of point-of-sale tobacco advertising and neighborhood characteristics to underage sales of tobacco. *Evaluation & the health professions.* 2012;35(3):331-345.

192. Paynter J, Edwards R. The impact of tobacco promotion at the point of sale: A systematic review. *Nicotine & Tobacco Research.* 2009;11(1):25-35.

193. McCarthy WJ, Mistry R, Lu Y, Patel M, Zheng H, Dietsch B. Density of Tobacco Retailers Near Schools: Effects on Tobacco Use Among Students. *American Journal of Public Health.* 2009;99(11):2006-2013.

194. Bunnell RE, Agaku IT, Arrazola R, et al. Intentions to smoke cigarettes among never-smoking US middle and high school electronic cigarette users, National Youth Tobacco Survey, 2011-2013. *Nicotine & Tobacco Research.* 2014:ntu166.

195. Feighery EC, Ribisl KM, Clark PI, Haladjian HH. How tobacco companies ensure prime placement of their advertising and products in stores: interviews with retailers about tobacco company incentive programmes. *Tobacco Control.* 2003;12(2):184-188.

Appendices

Appendix 2.1. *Code for SAS for Chapter 2*

```
*/importing for seperate data sets*/;
PROC IMPORT OUT= WORK.NCHAIIa
            DATAFILE= "C:\Users\micha\Dropbox\1. Dissertation\4. Paper 3\Data
Management\NCHA data ALL\NCHA-II F08 S09 F09 S10 F10 S11-R-BLIND-SAWDEY.sav"
            DBMS=SPSS REPLACE;
RUN;
PROC IMPORT OUT= WORK.NCHAIIb
            DATAFILE= "C:\Users\micha\Dropbox\1. Dissertation\4. Paper 3\Data
Management\NCHA data ALL\NCHA-II F11 S12 F12 S13 F13 S14 F14 S15 REFERENCE
GROUP-1R-BLIND-SAWDEY.sav"
            DBMS=SPSS REPLACE;
RUN;
PROC IMPORT OUT= WORK.NCHAIIc
            DATAFILE= "C:\Users\micha\Dropbox\1. Dissertation\4. Paper 3\Data
Management\NCHA data ALL\NCHA-II F15-R BLIND-SAWDEY.sav"
            DBMS=SPSS REPLACE;
RUN;
proc contents data=WORK.NCHAIIa order=varnum;run;
proc contents data=WORK.NCHAIIb order=varnum;run;
proc contents data=WORK.NCHAIIc order=varnum;run;

*/recoding gender prior to merging*/;
proc freq data=work.NCHAIIa;
table NQ47;run;
data WORK.NCHAIIa1; set WORK.NCHAIIa;
if NQ47=1 then Gender='1 Female'; */report female surveys before Fall 2015;
else if NQ47=2 then Gender='2 Male'; */report male surveys before Fall 2015;
else if NQ47=3 or NQ47=4 or NQ47=. then delete; */report transgender surveys
before Fall 2015;
run;
proc freq data=work.NCHAIIa1;
table Gender;run;

proc freq data=work.NCHAIIb;
table NQ47;run;
data WORK.NCHAIIb1; set WORK.NCHAIIb;
if NQ47=1 then Gender='1 Female'; */report female surveys before Fall 2015;
else if NQ47=2 then Gender='2 Male'; */report male surveys before Fall 2015;
else if NQ47=3 or NQ47=. then delete; */report transgender surveys before
Fall 2015;
run;
proc freq data=work.NCHAIIb1;
table Gender;run;

proc freq data=work.NCHAIIc;
table RNQ47a RNQ47b RNQ47c ;run;
data WORK.NCHAIIc1; set WORK.NCHAIIc;
```

```
if RNQ47a=1 and RNQ47c=1 then Gender='1 Female'; */report birth certificate
and identity as female Fall 2015 survey;
else if RNQ47a=2 and RNQ47c=2 then Gender='2 Male'; */report birth
certificate and identity as male Fall 2015 survey;
else if RNQ47a=2 and RNQ47c=1 then delete; */report birth certificate male
and identity as female Fall 2015 survey;
else if RNQ47a=1 and RNQ47c=2 then delete; */report birth certificate female
and identity as male Fall 2015 survey;
else if RNQ47b=2 then delete; */report  identity as transgender Fall 2015
survey;
else if RNQ47a=. or RNQ47b=. or RNQ47c=. then delete; */missing birth
certificate and identity Fall 2015 survey;
else if RNQ47c=3 or RNQ47c=4 or RNQ47c=5 or RNQ47c=6 then delete; */report
identity as Transmale, Transfemale, genderqueer, or other Fall 2015 survey;

*/ assigning study semesters to number 1-16;
proc freq data=WORK.NCHAIIa1;
table STUDY;run;
proc freq data=WORK.NCHAIIb1;
table STUDY;run;
proc freq data=WORK.NCHAIIc1;
table STUDY;run;
data work.NCHAIIa2; set work.NCHAIIa1;
if STUDY=18                         then Study_Semester=1;
else if STUDY=19                 then Study_Semester=2;
else if STUDY=20                 then Study_Semester=3;
else if STUDY=21               then Study_Semester=4;
else if STUDY=22               then Study_Semester=6;
else if STUDY=23               then Study_Semester=7;
run;
proc freq data=WORK.NCHAIIa2;
table Study_Semester;run;
data work.NCHAIIb2; set work.NCHAIIb1;
if STUDY=24                         then Study_Semester=8;
else if STUDY=25                 then Study_Semester=9;
else if STUDY=26                 then Study_Semester=10;
else if STUDY=27               then Study_Semester=11;
else if STUDY=28               then Study_Semester=12;
else if STUDY=29               then Study_Semester=13;
else if STUDY=30               then Study_Semester=14;
else if STUDY=31               then Study_Semester=15;
run;
proc freq data=WORK.NCHAIIb2;
table Study_Semester;run;
data work.NCHAIIc2; set work.NCHAIIc1;
if STUDY=32                         then Study_Semester=16;
run;
proc freq data=WORK.NCHAIIc2;
table Study_Semester;run;

*/merging data sets*******************/;
proc sort data=WORK.NCHAIIa2;
by Study_Semester;
run;
proc sort data=WORK.NCHAIIb2;
by Study_Semester;
run;
```

```
proc sort data=WORK.NCHAIIc2;
by Study_Semester;
run;
data work.merged;
merge WORK.NCHAIIa2 WORK.NCHAIIb2 WORK.NCHAIIc2;
by Study_Semester;
run;
proc freq data=work.merged;
table Study_Semester;
run;
proc freq data=work.merged;
table Gender;run;

*/ inclusion/exclusion criteria: 18-24 years old, male/female, US Region;
proc freq data=work.merged;
table REGION NQ46 NQ51 TYPE NQ58 SIZE  PUBPRIV LOCALE nq48 rnq48 NQ63 NQ53
NQ52;run;
data work.merged1; set work.merged;
if Region = 5 then delete;*/region;
if NQ46 > 24 or NQ46=. then delete;*/age over 24;
if NQ51=6 or NQ51=7 or NQ51=8 then delete; */ Graduate/Professional, not
seeking degree, other;
if TYPE=1 or TYPE=3 then delete; /* remove 2-year schools;*/
if NQ58=1 then Live_recode='1 live on campus'; */recoding where they live as
on or off campus;
else if NQ58=2 then Live_recode='1 live on campus';
else if NQ58=3 then Live_recode='1 live on campus';
else if NQ58=4 then Live_recode='2 live off campus';
else if NQ58=5 then Live_recode='2 live off campus';
else if NQ58=6 then Live_recode='2 live off campus';
if SIZE =1 then SIZE_recode='1 small campus <=5k';
else if SIZE =2 then SIZE_recode='1 small campus <=5k';
else if SIZE =3 then SIZE_recode='2 medium campus >5 to <20k';
else if SIZE =4 then SIZE_recode='3 large campus >=20k';
else if SIZE =5 then SIZE_recode='3 large campus >=20k';
if LOCALE=1 then LOCALE_recode='1 small locale <50k';
else if LOCALE=2 then LOCALE_recode='1 small locale <50k';
else if LOCALE=3 then LOCALE_recode='1 small locale <50k';
else if LOCALE=4 then LOCALE_recode='2 medium locale 50k-250k';
else if LOCALE=5 then LOCALE_recode='3 large locale >250k';
else if LOCALE=6 then LOCALE_recode='3 large locale >250k';
if NQ48=1 or RNQ48=9 then Sex_or= 1;
else if nq48=2 or nq48=3 or nq48=4 or RNQ48=1 or RNQ48=2 or RNQ48=3 or
RNQ48=4 or RNQ48=5 or RNQ48=6 or RNQ48=7 or RNQ48=8  or RNQ48=10 then
Sex_or=2;
else if nq48=. and RNQ48=. then Sex_or=.;
if NQ63 = 5 then nq63=.;
if nq52=3 then nq52=.;
run;
proc freq data=work.merged1;
table GENDER REGION NQ46 NQ51 TYPE Live_recode SIZE_recode PUBPRIV
LOCALE_recode Sex_or NQ63 NQ52;run;
proc freq data=work.merged1;
table nq48 rnq48 Sex_or;run;

*/Recoding the seperate race variables, into 1 variable with 5 levels
1= White
```

```
2=Black
3=Hispanic
4=Asian
5=Other*/;
proc freq data=work.merged1;
table NQ54A NQ54b NQ54C NQ54D NQ54E NQ54F NQ54G;
run;
data work.merged2; set work.merged1;
if          NQ54A=1     THEN White=1;
else if NQ54A=0   THEN White=0;
else if     NQ54A=.     THEN White=.;
if          NQ54B=1     THEN Black=1;
else if     NQ54B=0     THEN Black=0;
else if     NQ54B=.     THEN Black=.;
if          NQ54D=1     THEN Asian=1;
else if     NQ54D=0     THEN Asian=0;
else if     NQ54D=.     THEN Asian=.;
if          NQ54C=1     then Hispanic=1;
else if     NQ54C=0     then Hispanic=0;
else if NQ54C= .  then Hispanic=.;
if    NQ54E=1 or  NQ54F=1 or  NQ54g=1 then Other=1;
else if NQ54E=0 and NQ54F=0 and NQ54g=0 then Other=0;
else if NQ54E=. and NQ54F=. and NQ54g=. then Other=.;
run;
proc freq data=work.merged2;
table White Black Hispanic Asian Other;;
run;
data work.merged3; set work.merged2;
if Hispanic=1     then White=0;
if Hispanic=1     then Black=0;
if Hispanic=1     then Asian=0;
if Hispanic=1     then Other=0;
if Other=1        then White=0;
if Other=1        then Black=0;
if Other=1        then Asian=0;
if Other=1        then Hispanic=0;
run;
data work.merged4; set work.merged3;
if          White=1 and Black=0 or Asian=0      then Race=1;
else if White=1 and Black=. or Asian=0    then Race=1;
else if White=1 and Black=0 or Asian=.    then Race=1;
else if White=1 and Black=. or Asian=.    then Race=1;
if White=0 and Black=1 or Asian=0         then Race=2;
else if White=. and Black=1 or Asian=0    then Race=2;
else if White=0 and Black=1 or Asian=.    then Race=2;
else if White=. and Black=1 or Asian=.    then Race=2;
if White=0 and Black=0 or Asian=1         then Race=3;
else if White=. and Black=0 or Asian=1    then Race=3;
else if White=0 and Black=. or Asian=1    then Race=3;
else if White=. and Black=. or Asian=1    then Race=3;
if Hispanic = 1                                 then Race=4;
if Other=1                                            then Race=5;
else if White=1 and Black=1               then Race=5;
else if White=1 and Asian=1               then Race=5;
else if Black=1 and Asian=1               then Race=5;
if          White=. and Black=. and Asian=. and Hispanic=. and Other=. then
Race=.;
```

```
if          White=0 and Black=0 and Asian=0 and Hispanic=0 and Other=0 then
Race=.;
run;
proc freq data=work.merged4;
table Race;
run;

*/ Recoding Substance use and percevied peer use Variables for 2-level, 3-
level, 4 level, ever, and poly-tobacco use*/;
Proc freq data=work.merged4;
table NQ8A1 NQ8A2 NQ8A3 NQ8A4 NQ8A5 NQ8A6 NQ8A10;run;
data work.merged5;set work.merged4;
*/Recode all substance use variables into Yes/No*
0=never, have used but not in last 30
1= 1+ days/;
if NQ8A1=1 then Cigs_2lvl=0;
else if NQ8A1=2 then Cigs_2lvl=0;
else if NQ8A1=3 then Cigs_2lvl=1;
else if NQ8A1=4 then Cigs_2lvl=1;
else if NQ8A1=5 then Cigs_2lvl=1;
else if NQ8A1=6 then Cigs_2lvl=1;
else if NQ8A1=7 then Cigs_2lvl=1;
else if NQ8A1=8 then Cigs_2lvl=1;
if NQ8A2=1 then Hookah_2lvl=0;
else if NQ8A2=2 then Hookah_2lvl=0;
else if NQ8A2=3 then Hookah_2lvl=1;
else if NQ8A2=4 then Hookah_2lvl=1;
else if NQ8A2=5 then Hookah_2lvl=1;
else if NQ8A2=6 then Hookah_2lvl=1;
else if NQ8A2=7 then Hookah_2lvl=1;
else if NQ8A2=8 then Hookah_2lvl=1;
 if NQ8A3=1 then Cigar_2lvl=0;
else if NQ8A3=2 then Cigar_2lvl=0;
else if NQ8A3=3 then Cigar_2lvl=1;
else if NQ8A3=4 then Cigar_2lvl=1;
else if NQ8A3=5 then Cigar_2lvl=1;
else if NQ8A3=6 then Cigar_2lvl=1;
else if NQ8A3=7 then Cigar_2lvl=1;
else if NQ8A3=8 then Cigar_2lvl=1;
if NQ8A4=1 then Smkless_2lvl=0;
else if NQ8A4=2 then Smkless_2lvl=0;
else if NQ8A4=3 then Smkless_2lvl=1;
else if NQ8A4=4 then Smkless_2lvl=1;
else if NQ8A4=5 then Smkless_2lvl=1;
else if NQ8A4=6 then Smkless_2lvl=1;
else if NQ8A4=7 then Smkless_2lvl=1;
else if NQ8A4=8 then Smkless_2lvl=1;
if NQ8A5=1 then Alcohol_2lvl=0;
else if NQ8A5=2 then Alcohol_2lvl=0;
else if NQ8A5=3 then Alcohol_2lvl=1;
else if NQ8A5=4 then Alcohol_2lvl=1;
else if NQ8A5=5 then Alcohol_2lvl=1;
else if NQ8A5=6 then Alcohol_2lvl=1;
else if NQ8A5=7 then Alcohol_2lvl=1;
else if NQ8A5=8 then Alcohol_2lvl=1;
if NQ8A6=1 then Marij_2lvl=0;
else if NQ8A6=2 then Marij_2lvl=0;
```

```
else if NQ8A6=3 then Marij_2lvl=1;
else if NQ8A6=4 then Marij_2lvl=1;
else if NQ8A6=5 then Marij_2lvl=1;
else if NQ8A6=6 then Marij_2lvl=1;
else if NQ8A6=7 then Marij_2lvl=1;
else if NQ8A6=8 then Marij_2lvl=1;
if NQ8A10=1 then Ecigs_2lvl=0;
else if NQ8A10=2 then Ecigs_2lvl=0;
else if NQ8A10=3 then Ecigs_2lvl=1;
else if NQ8A10=4 then Ecigs_2lvl=1;
else if NQ8A10=5 then Ecigs_2lvl=1;
else if NQ8A10=6 then Ecigs_2lvl=1;
else if NQ8A10=7 then Ecigs_2lvl=1;
else if NQ8A10=8 then Ecigs_2lvl=1;
*/recoding to 3 level*/;
*/0=never use, have used but not in the 30 days;
*/1= 1-9 days;
*/2= 10 or more days;
if NQ8A1=1 then Cigs_3lvl=0;
else if NQ8A1=2 then Cigs_3lvl=0;
else if NQ8A1=3 then Cigs_3lvl=1;
else if NQ8A1=4 then Cigs_3lvl=1;
else if NQ8A1=5 then Cigs_3lvl=1;
else if NQ8A1=6 then Cigs_3lvl=2;
else if NQ8A1=7 then Cigs_3lvl=2;
else if NQ8A1=8 then Cigs_3lvl=2;
if NQ8A2=1 then Hookah_3lvl=0;
else if NQ8A2=2 then Hookah_3lvl=0;
else if NQ8A2=3 then Hookah_3lvl=1;
else if NQ8A2=4 then Hookah_3lvl=1;
else if NQ8A2=5 then Hookah_3lvl=1;
else if NQ8A2=6 then Hookah_3lvl=2;
else if NQ8A2=7 then Hookah_3lvl=2;
else if NQ8A2=8 then Hookah_3lvl=2;
 if NQ8A3=1 then Cigar_3lvl=0;
else if NQ8A3=2 then Cigar_3lvl=0;
else if NQ8A3=3 then Cigar_3lvl=1;
else if NQ8A3=4 then Cigar_3lvl=1;
else if NQ8A3=5 then Cigar_3lvl=1;
else if NQ8A3=6 then Cigar_3lvl=2;
else if NQ8A3=7 then Cigar_3lvl=2;
else if NQ8A3=8 then Cigar_3lvl=2;
if NQ8A4=1 then Smkless_3lvl=0;
else if NQ8A4=2 then Smkless_3lvl=0;
else if NQ8A4=3 then Smkless_3lvl=1;
else if NQ8A4=4 then Smkless_3lvl=1;
else if NQ8A4=5 then Smkless_3lvl=1;
else if NQ8A4=6 then Smkless_3lvl=2;
else if NQ8A4=7 then Smkless_3lvl=2;
else if NQ8A4=8 then Smkless_3lvl=2;
if NQ8A5=1 then Alcohol_3lvl=0;
else if NQ8A5=2 then Alcohol_3lvl=0;
else if NQ8A5=3 then Alcohol_3lvl=1;
else if NQ8A5=4 then Alcohol_3lvl=1;
else if NQ8A5=5 then Alcohol_3lvl=1;
else if NQ8A5=6 then Alcohol_3lvl=2;
else if NQ8A5=7 then Alcohol_3lvl=2;
```

```
else if NQ8A5=8 then Alcohol_3lvl=2;
if NQ8A6=1 then Marij_3lvl=0;
else if NQ8A6=2 then Marij_3lvl=0;
else if NQ8A6=3 then Marij_3lvl=1;
else if NQ8A6=4 then Marij_3lvl=1;
else if NQ8A6=5 then Marij_3lvl=1;
else if NQ8A6=6 then Marij_3lvl=2;
else if NQ8A6=7 then Marij_3lvl=2;
else if NQ8A6=8 then Marij_3lvl=2;
if NQ8A10=1 then Ecigs_3lvl=0;
else if NQ8A10=2 then Ecigs_3lvl=0;
else if NQ8A10=3 then Ecigs_3lvl=1;
else if NQ8A10=4 then Ecigs_3lvl=1;
else if NQ8A10=5 then Ecigs_3lvl=1;
else if NQ8A10=6 then Ecigs_3lvl=2;
else if NQ8A10=7 then Ecigs_3lvl=2;
else if NQ8A10=8 then Ecigs_3lvl=2;
*/recoding to 4 level*/;
*/0=never use, have used but not in the 30 days;
*/1= 1-9days;
*/2= 10-29 days;
*/3= Daily;
if NQ8A1=1 then Cigs_4lvl=0;
else if NQ8A1=2 then Cigs_4lvl=0;
else if NQ8A1=3 then Cigs_4lvl=1;
else if NQ8A1=4 then Cigs_4lvl=1;
else if NQ8A1=5 then Cigs_4lvl=1;
else if NQ8A1=6 then Cigs_4lvl=2;
else if NQ8A1=7 then Cigs_4lvl=2;
else if NQ8A1=8 then Cigs_4lvl=3;
if NQ8A2=1 then Hookah_4lvl=0;
else if NQ8A2=2 then Hookah_4lvl=0;
else if NQ8A2=3 then Hookah_4lvl=1;
else if NQ8A2=4 then Hookah_4lvl=1;
else if NQ8A2=5 then Hookah_4lvl=1;
else if NQ8A2=6 then Hookah_4lvl=2;
else if NQ8A2=7 then Hookah_4lvl=2;
else if NQ8A2=8 then Hookah_4lvl=3;
 if NQ8A3=1 then Cigar_4lvl=0;
else if NQ8A3=2 then Cigar_4lvl=0;
else if NQ8A3=3 then Cigar_4lvl=1;
else if NQ8A3=4 then Cigar_4lvl=1;
else if NQ8A3=5 then Cigar_4lvl=2;
else if NQ8A3=6 then Cigar_4lvl=2;
else if NQ8A3=7 then Cigar_4lvl=2;
else if NQ8A3=8 then Cigar_4lvl=3;
if NQ8A4=1 then Smkless_4lvl=0;
else if NQ8A4=2 then Smkless_4lvl=0;
else if NQ8A4=3 then Smkless_4lvl=1;
else if NQ8A4=4 then Smkless_4lvl=1;
else if NQ8A4=5 then Smkless_4lvl=2;
else if NQ8A4=6 then Smkless_4lvl=2;
else if NQ8A4=7 then Smkless_4lvl=2;
else if NQ8A4=8 then Smkless_4lvl=3;
if NQ8A5=1 then Alcohol_4lvl=0;
else if NQ8A5=2 then Alcohol_4lvl=0;
else if NQ8A5=3 then Alcohol_4lvl=1;
```

```
else if NQ8A5=4 then Alcohol_4lvl=1;
else if NQ8A5=5 then Alcohol_4lvl=2;
else if NQ8A5=6 then Alcohol_4lvl=2;
else if NQ8A5=7 then Alcohol_4lvl=2;
else if NQ8A5=8 then Alcohol_4lvl=3;
if NQ8A6=1 then Marij_4lvl=0;
else if NQ8A6=2 then Marij_4lvl=0;
else if NQ8A6=3 then Marij_4lvl=1;
else if NQ8A6=4 then Marij_4lvl=1;
else if NQ8A6=5 then Marij_4lvl=2;
else if NQ8A6=6 then Marij_4lvl=2;
else if NQ8A6=7 then Marij_4lvl=2;
else if NQ8A6=8 then Marij_4lvl=3;
if NQ8A10=1 then Ecigs_4lvl=0;
else if NQ8A10=2 then Ecigs_4lvl=0;
else if NQ8A10=3 then Ecigs_4lvl=1;
else if NQ8A10=4 then Ecigs_4lvl=1;
else if NQ8A10=5 then Ecigs_4lvl=2;
else if NQ8A10=6 then Ecigs_4lvl=2;
else if NQ8A10=7 then Ecigs_4lvl=2;
else if NQ8A10=8 then Ecigs_4lvl=3;
*/Ever use of substances;
*/0=never use, ;
*/1= have used but not in the 30 days or 1+days;
if NQ8A1=1 then Cigs_ever=0;
else if NQ8A1=2 then Cigs_ever=1;
else if NQ8A1=3 then Cigs_ever=1;
else if NQ8A1=4 then Cigs_ever=1;
else if NQ8A1=5 then Cigs_ever=1;
else if NQ8A1=6 then Cigs_ever=1;
else if NQ8A1=7 then Cigs_ever=1;
else if NQ8A1=8 then Cigs_ever=1;
if NQ8A2=1 then Hookah_ever=0;
else if NQ8A2=2 then Hookah_ever=1;
else if NQ8A2=3 then Hookah_ever=1;
else if NQ8A2=4 then Hookah_ever=1;
else if NQ8A2=5 then Hookah_ever=1;
else if NQ8A2=6 then Hookah_ever=1;
else if NQ8A2=7 then Hookah_ever=1;
else if NQ8A2=8 then Hookah_ever=1;
 if NQ8A3=1 then Cigar_ever=0;
else if NQ8A3=2 then Cigar_ever=1;
else if NQ8A3=3 then Cigar_ever=1;
else if NQ8A3=4 then Cigar_ever=1;
else if NQ8A3=5 then Cigar_ever=1;
else if NQ8A3=6 then Cigar_ever=1;
else if NQ8A3=7 then Cigar_ever=1;
else if NQ8A3=8 then Cigar_ever=1;
if NQ8A4=1 then Smkless_ever=0;
else if NQ8A4=2 then Smkless_ever=1;
else if NQ8A4=3 then Smkless_ever=1;
else if NQ8A4=4 then Smkless_ever=1;
else if NQ8A4=5 then Smkless_ever=1;
else if NQ8A4=6 then Smkless_ever=1;
else if NQ8A4=7 then Smkless_ever=1;
else if NQ8A4=8 then Smkless_ever=1;
if NQ8A5=1 then Alcohol_ever=0;
```

```
else if NQ8A5=2 then Alcohol_ever=1;
else if NQ8A5=3 then Alcohol_ever=1;
else if NQ8A5=4 then Alcohol_ever=1;
else if NQ8A5=5 then Alcohol_ever=1;
else if NQ8A5=6 then Alcohol_ever=1;
else if NQ8A5=7 then Alcohol_ever=1;
else if NQ8A5=8 then Alcohol_ever=1;
if NQ8A6=1 then Marij_ever=0;
else if NQ8A6=2 then Marij_ever=1;
else if NQ8A6=3 then Marij_ever=1;
else if NQ8A6=4 then Marij_ever=1;
else if NQ8A6=5 then Marij_ever=1;
else if NQ8A6=6 then Marij_ever=1;
else if NQ8A6=7 then Marij_ever=1;
else if NQ8A6=8 then Marij_ever=1;
if NQ8A10=1 then Ecigs_ever=0;
else if NQ8A10=2 then Ecigs_ever=1;
else if NQ8A10=3 then Ecigs_ever=1;
else if NQ8A10=4 then Ecigs_ever=1;
else if NQ8A10=5 then Ecigs_ever=1;
else if NQ8A10=6 then Ecigs_ever=1;
else if NQ8A10=7 then Ecigs_ever=1;
else if NQ8A10=8 then Ecigs_ever=1;
/*Recode for binge drinking into 2lvl(yes/no) or 3 level (1 or 2 times/3+*/;
if NQ13 = 1 OR NQ13=2 then BINGE_2lvl=0;
else if NQ13 = 3 OR NQ13=4 or NQ13=5 or NQ13 =6 OR NQ13=7 OR NQ13=8 OR NQ13=9
OR NQ13=10 or NQ13 = 11 OR NQ13=12 THEN BINGE_2lvl=1;
if NQ13 = 1 OR NQ13=2 then BINGE_3lvl=0;
else if NQ13 = 3 then BINGE_3lvl=1;
else if NQ13=4 or NQ13=5 or NQ13 =6 OR NQ13=7 OR NQ13=8 OR NQ13=9 OR NQ13=10
or NQ13 = 11 OR NQ13=12 THEN BINGE_3lvl=2;
run;
proc freq data=work.merged5;
table cigs_2lvl hookah_2lvl cigar_2lvl smkless_2lvl alcohol_2lvl marij_2lvl
ecigs_2lvl
        cigs_3lvl hookah_3lvl cigar_3lvl smkless_3lvl alcohol_3lvl marij_3lvl
ecigs_3lvl
        cigs_4lvl hookah_4lvl cigar_4lvl smkless_4lvl alcohol_4lvl marij_4lvl
ecigs_4lvl
        cigs_ever hookah_ever cigar_ever smkless_ever alcohol_ever marij_ever
ecigs_ever;
        run;

*/ Percevied peer use of substances;
data work.merged6; set work.merged5;
*/ Percieve any peer use
*/0=never, have used but not in last 30
1= 1+ days/;
if NQ9A1=1 then Perc_Cigs_2lvl=0;
else if NQ9A1=2 then Perc_Cigs_2lvl=0;
else if NQ9A1=3 then Perc_Cigs_2lvl=1;
else if NQ9A1=4 then Perc_Cigs_2lvl=1;
else if NQ9A1=5 then Perc_Cigs_2lvl=1;
else if NQ9A1=6 then Perc_Cigs_2lvl=1;
else if NQ9A1=7 then Perc_Cigs_2lvl=1;
else if NQ9A1=8 then Perc_Cigs_2lvl=1;
if NQ9A2=1 then Perc_Hookah_2lvl=0;
```

```
else if NQ9A2=2 then Perc_Hookah_2lvl=0;
else if NQ9A2=3 then Perc_Hookah_2lvl=1;
else if NQ9A2=4 then Perc_Hookah_2lvl=1;
else if NQ9A2=5 then Perc_Hookah_2lvl=1;
else if NQ9A2=6 then Perc_Hookah_2lvl=1;
else if NQ9A2=7 then Perc_Hookah_2lvl=1;
else if NQ9A2=8 then Perc_Hookah_2lvl=1;
 if NQ9A3=1 then Perc_Cigar_2lvl=0;
else if NQ9A3=2 then Perc_Cigar_2lvl=0;
else if NQ9A3=3 then Perc_Cigar_2lvl=1;
else if NQ9A3=4 then Perc_Cigar_2lvl=1;
else if NQ9A3=5 then Perc_Cigar_2lvl=1;
else if NQ9A3=6 then Perc_Cigar_2lvl=1;
else if NQ9A3=7 then Perc_Cigar_2lvl=1;
else if NQ9A3=8 then Perc_Cigar_2lvl=1;
if NQ9A4=1 then Perc_Smkless_2lvl=0;
else if NQ9A4=2 then Perc_Smkless_2lvl=0;
else if NQ9A4=3 then Perc_Smkless_2lvl=1;
else if NQ9A4=4 then Perc_Smkless_2lvl=1;
else if NQ9A4=5 then Perc_Smkless_2lvl=1;
else if NQ9A4=6 then Perc_Smkless_2lvl=1;
else if NQ9A4=7 then Perc_Smkless_2lvl=1;
else if NQ9A4=8 then Perc_Smkless_2lvl=1;
if NQ9A5=1 then Perc_Alcohol_2lvl=0;
else if NQ9A5=2 then Perc_Alcohol_2lvl=0;
else if NQ9A5=3 then Perc_Alcohol_2lvl=1;
else if NQ9A5=4 then Perc_Alcohol_2lvl=1;
else if NQ9A5=5 then Perc_Alcohol_2lvl=1;
else if NQ9A5=6 then Perc_Alcohol_2lvl=1;
else if NQ9A5=7 then Perc_Alcohol_2lvl=1;
else if NQ9A5=8 then Perc_Alcohol_2lvl=1;
if NQ9A6=1 then Perc_Marij_2lvl=0;
else if NQ9A6=2 then Perc_Marij_2lvl=0;
else if NQ9A6=3 then Perc_Marij_2lvl=1;
else if NQ9A6=4 then Perc_Marij_2lvl=1;
else if NQ9A6=5 then Perc_Marij_2lvl=1;
else if NQ9A6=6 then Perc_Marij_2lvl=1;
else if NQ9A6=7 then Perc_Marij_2lvl=1;
else if NQ9A6=8 then Perc_Marij_2lvl=1;
if NQ9A10=1 then Perc_Ecigs_2lvl=0;
else if NQ9A10=2 then Perc_Ecigs_2lvl=0;
else if NQ9A10=3 then Perc_Ecigs_2lvl=1;
else if NQ9A10=4 then Perc_Ecigs_2lvl=1;
else if NQ9A10=5 then Perc_Ecigs_2lvl=1;
else if NQ9A10=6 then Perc_Ecigs_2lvl=1;
else if NQ9A10=7 then Perc_Ecigs_2lvl=1;
else if NQ9A10=8 then Perc_Ecigs_2lvl=1;
*/ Percieve 3 level
*/0=never use, have used but not in the 30 days;
*/1= 1-9 days;
*/2= 10 or more days;
if NQ9A1=1 then Perc_Cigs_3lvl=0;
else if NQ9A1=2 then Perc_Cigs_3lvl=0;
else if NQ9A1=3 then Perc_Cigs_3lvl=1;
else if NQ9A1=4 then Perc_Cigs_3lvl=1;
else if NQ9A1=5 then Perc_Cigs_3lvl=1;
else if NQ9A1=6 then Perc_Cigs_3lvl=2;
```

```
else if NQ9A1=7 then Perc_Cigs_3lvl=2;
else if NQ9A1=8 then Perc_Cigs_3lvl=2;
if NQ9A2=1 then Perc_Hookah_3lvl=0;
else if NQ9A2=2 then Perc_Hookah_3lvl=0;
else if NQ9A2=3 then Perc_Hookah_3lvl=1;
else if NQ9A2=4 then Perc_Hookah_3lvl=1;
else if NQ9A2=5 then Perc_Hookah_3lvl=1;
else if NQ9A2=6 then Perc_Hookah_3lvl=2;
else if NQ9A2=7 then Perc_Hookah_3lvl=2;
else if NQ9A2=8 then Perc_Hookah_3lvl=2;
 if NQ9A3=1 then Perc_Cigar_3lvl=0;
else if NQ9A3=2 then Perc_Cigar_3lvl=0;
else if NQ9A3=3 then Perc_Cigar_3lvl=1;
else if NQ9A3=4 then Perc_Cigar_3lvl=1;
else if NQ9A3=5 then Perc_Cigar_3lvl=1;
else if NQ9A3=6 then Perc_Cigar_3lvl=2;
else if NQ9A3=7 then Perc_Cigar_3lvl=2;
else if NQ9A3=8 then Perc_Cigar_3lvl=2;
if NQ9A4=1 then Perc_Smkless_3lvl=0;
else if NQ9A4=2 then Perc_Smkless_3lvl=0;
else if NQ9A4=3 then Perc_Smkless_3lvl=1;
else if NQ9A4=4 then Perc_Smkless_3lvl=1;
else if NQ9A4=5 then Perc_Smkless_3lvl=1;
else if NQ9A4=6 then Perc_Smkless_3lvl=2;
else if NQ9A4=7 then Perc_Smkless_3lvl=2;
else if NQ9A4=8 then Perc_Smkless_3lvl=2;
if NQ9A5=1 then Perc_Alcohol_3lvl=0;
else if NQ9A5=2 then Perc_Alcohol_3lvl=0;
else if NQ9A5=3 then Perc_Alcohol_3lvl=1;
else if NQ9A5=4 then Perc_Alcohol_3lvl=1;
else if NQ9A5=5 then Perc_Alcohol_3lvl=1;
else if NQ9A5=6 then Perc_Alcohol_3lvl=2;
else if NQ9A5=7 then Perc_Alcohol_3lvl=2;
else if NQ9A5=8 then Perc_Alcohol_3lvl=2;
if NQ9A6=1 then Perc_Marij_3lvl=0;
else if NQ9A6=2 then Perc_Marij_3lvl=0;
else if NQ9A6=3 then Perc_Marij_3lvl=1;
else if NQ9A6=4 then Perc_Marij_3lvl=1;
else if NQ9A6=5 then Perc_Marij_3lvl=1;
else if NQ9A6=6 then Perc_Marij_3lvl=2;
else if NQ9A6=7 then Perc_Marij_3lvl=2;
else if NQ9A6=8 then Perc_Marij_3lvl=2;
if NQ9A10=1 then Perc_Ecigs_3lvl=0;
else if NQ9A10=2 then Perc_Ecigs_3lvl=0;
else if NQ9A10=3 then Perc_Ecigs_3lvl=1;
else if NQ9A10=4 then Perc_Ecigs_3lvl=1;
else if NQ9A10=5 then Perc_Ecigs_3lvl=1;
else if NQ9A10=6 then Perc_Ecigs_3lvl=2;
else if NQ9A10=7 then Perc_Ecigs_3lvl=2;
else if NQ9A10=8 then Perc_Ecigs_3lvl=2;
*/ Percieve 4 level
*/0=never use, have used but not in the 30 days;
*/1= 1-9days;
*/2= 10-29 days;
*/3= Daily;
if NQ9A1=1 then Perc_Cigs_4lvl=0;
else if NQ9A1=2 then Perc_Cigs_4lvl=0;
```

```
else if NQ9A1=3 then Perc_Cigs_4lvl=1;
else if NQ9A1=4 then Perc_Cigs_4lvl=1;
else if NQ9A1=5 then Perc_Cigs_4lvl=1;
else if NQ9A1=6 then Perc_Cigs_4lvl=2;
else if NQ9A1=7 then Perc_Cigs_4lvl=2;
else if NQ9A1=8 then Perc_Cigs_4lvl=3;
if NQ9A2=1 then Perc_Hookah_4lvl=0;
else if NQ9A2=2 then Perc_Hookah_4lvl=0;
else if NQ9A2=3 then Perc_Hookah_4lvl=1;
else if NQ9A2=4 then Perc_Hookah_4lvl=1;
else if NQ9A2=5 then Perc_Hookah_4lvl=1;
else if NQ9A2=6 then Perc_Hookah_4lvl=2;
else if NQ9A2=7 then Perc_Hookah_4lvl=2;
else if NQ9A2=8 then Perc_Hookah_4lvl=3;
 if NQ9A3=1 then Perc_Cigar_4lvl=0;
else if NQ9A3=2 then Perc_Cigar_4lvl=0;
else if NQ9A3=3 then Perc_Cigar_4lvl=1;
else if NQ9A3=4 then Perc_Cigar_4lvl=1;
else if NQ9A3=5 then Perc_Cigar_4lvl=1;
else if NQ9A3=6 then Perc_Cigar_4lvl=2;
else if NQ9A3=7 then Perc_Cigar_4lvl=2;
else if NQ9A3=8 then Perc_Cigar_4lvl=3;
if NQ9A4=1 then Perc_Smkless_4lvl=0;
else if NQ9A4=2 then Perc_Smkless_4lvl=0;
else if NQ9A4=3 then Perc_Smkless_4lvl=1;
else if NQ9A4=4 then Perc_Smkless_4lvl=1;
else if NQ9A4=5 then Perc_Smkless_4lvl=1;
else if NQ9A4=6 then Perc_Smkless_4lvl=2;
else if NQ9A4=7 then Perc_Smkless_4lvl=2;
else if NQ9A4=8 then Perc_Smkless_4lvl=3;
if NQ9A5=1 then Perc_Alcohol_4lvl=0;
else if NQ9A5=2 then Perc_Alcohol_4lvl=0;
else if NQ9A5=3 then Perc_Alcohol_4lvl=1;
else if NQ9A5=4 then Perc_Alcohol_4lvl=1;
else if NQ9A5=5 then Perc_Alcohol_4lvl=1;
else if NQ9A5=6 then Perc_Alcohol_4lvl=2;
else if NQ9A5=7 then Perc_Alcohol_4lvl=2;
else if NQ9A5=8 then Perc_Alcohol_4lvl=3;
if NQ9A6=1 then Perc_Marij_4lvl=0;
else if NQ9A6=2 then Perc_Marij_4lvl=0;
else if NQ9A6=3 then Perc_Marij_4lvl=1;
else if NQ9A6=4 then Perc_Marij_4lvl=1;
else if NQ9A6=5 then Perc_Marij_4lvl=1;
else if NQ9A6=6 then Perc_Marij_4lvl=2;
else if NQ9A6=7 then Perc_Marij_4lvl=2;
else if NQ9A6=8 then Perc_Marij_4lvl=3;
if NQ9A10=1 then Perc_Ecigs_4lvl=0;
else if NQ9A10=2 then Perc_Ecigs_4lvl=0;
else if NQ9A10=3 then Perc_Ecigs_4lvl=1;
else if NQ9A10=4 then Perc_Ecigs_4lvl=1;
else if NQ9A10=5 then Perc_Ecigs_4lvl=1;
else if NQ9A10=6 then Perc_Ecigs_4lvl=2;
else if NQ9A10=7 then Perc_Ecigs_4lvl=2;
else if NQ9A10=8 then Perc_Ecigs_4lvl=3;
*/Percevie Ever Use*/
*/0=never use, ;
*/1= have used but not in the 30 days or 1+days;
```

```
if NQ9A1=1 then Perc_Cigs_ever=0;
else if NQ9A1=2 then Perc_Cigs_ever=1;
else if NQ9A1=3 then Perc_Cigs_ever=1;
else if NQ9A1=4 then Perc_Cigs_ever=1;
else if NQ9A1=5 then Perc_Cigs_ever=1;
else if NQ9A1=6 then Perc_Cigs_ever=1;
else if NQ9A1=7 then Perc_Cigs_ever=1;
else if NQ9A1=8 then Perc_Cigs_ever=1;
if NQ9A2=1 then Perc_Hookah_ever=0;
else if NQ9A2=2 then Perc_Hookah_ever=1;
else if NQ9A2=3 then Perc_Hookah_ever=1;
else if NQ9A2=4 then Perc_Hookah_ever=1;
else if NQ9A2=5 then Perc_Hookah_ever=1;
else if NQ9A2=6 then Perc_Hookah_ever=1;
else if NQ9A2=7 then Perc_Hookah_ever=1;
else if NQ9A2=8 then Perc_Hookah_ever=1;
 if NQ9A3=1 then Perc_Cigar_ever=0;
else if NQ9A3=2 then Perc_Cigar_ever=1;
else if NQ9A3=3 then Perc_Cigar_ever=1;
else if NQ9A3=4 then Perc_Cigar_ever=1;
else if NQ9A3=5 then Perc_Cigar_ever=1;
else if NQ9A3=6 then Perc_Cigar_ever=1;
else if NQ9A3=7 then Perc_Cigar_ever=1;
else if NQ9A3=8 then Perc_Cigar_ever=1;
if NQ9A4=1 then Perc_Smkless_ever=0;
else if NQ9A4=2 then Perc_Smkless_ever=1;
else if NQ9A4=3 then Perc_Smkless_ever=1;
else if NQ9A4=4 then Perc_Smkless_ever=1;
else if NQ9A4=5 then Perc_Smkless_ever=1;
else if NQ9A4=6 then Perc_Smkless_ever=1;
else if NQ9A4=7 then Perc_Smkless_ever=1;
else if NQ9A4=8 then Perc_Smkless_ever=1;
if NQ9A5=1 then Perc_Alcohol_ever=0;
else if NQ9A5=2 then Perc_Alcohol_ever=1;
else if NQ9A5=3 then Perc_Alcohol_ever=1;
else if NQ9A5=4 then Perc_Alcohol_ever=1;
else if NQ9A5=5 then Perc_Alcohol_ever=1;
else if NQ9A5=6 then Perc_Alcohol_ever=1;
else if NQ9A5=7 then Perc_Alcohol_ever=1;
else if NQ9A5=8 then Perc_Alcohol_ever=1;
if NQ9A6=1 then Perc_Marij_ever=0;
else if NQ9A6=2 then Perc_Marij_ever=1;
else if NQ9A6=3 then Perc_Marij_ever=1;
else if NQ9A6=4 then Perc_Marij_ever=1;
else if NQ9A6=5 then Perc_Marij_ever=1;
else if NQ9A6=6 then Perc_Marij_ever=1;
else if NQ9A6=7 then Perc_Marij_ever=1;
else if NQ9A6=8 then Perc_Marij_ever=1;
if NQ9A10=1 then Perc_Ecigs_ever=0;
else if NQ9A10=2 then Perc_Ecigs_ever=1;
else if NQ9A10=3 then Perc_Ecigs_ever=1;
else if NQ9A10=4 then Perc_Ecigs_ever=1;
else if NQ9A10=5 then Perc_Ecigs_ever=1;
else if NQ9A10=6 then Perc_Ecigs_ever=1;
else if NQ9A10=7 then Perc_Ecigs_ever=1;
else if NQ9A10=8 then Perc_Ecigs_ever=1;
run;
```

```
*/any or dual or poly substance/tobacco use*/;
data  work.merged7 ;
set work.merged6 ;
use_composite =   sum(Cigs_2lvl, Hookah_2lvl , Cigar_2lvl , Smkless_2lvl ,
Alcohol_2lvl , Marij_2lvl, ecigs_2lvl);
perc_composite =  sum(Perc_Cigs_2lvl , Perc_Hookah_2lvl , Perc_Cigar_2lvl ,
Perc_Smkless_2lvl,  Perc_Alcohol_2lvl , Perc_Marij_2lvl, perc_ecigs_2lvl);
tobacco_composite = sum(Cigs_2lvl , Hookah_2lvl , Cigar_2lvl , Smkless_2lvl,
ecigs_2lvl);
Perc_tob_composite = sum(Perc_Cigs_2lvl , Perc_Hookah_2lvl , Perc_Cigar_2lvl
, Perc_Smkless_2lvl, perc_ecigs_2lvl);
run;
proc freq data=work.merged7;
table use_composite perc_composite tobacco_composite Perc_tob_composite;
run;
data  work.merged8; set work.merged7;
if use_composite>0 then any_substance=1;
else if use_composite=0 then any_substance=0;
else if use_composite=. then any_substance=.;
if use_composite=1 or use_composite =0 then poly_substance=0;
else if use_composite>1 then poly_substance=1;
else if use_composite=. then poly_substance=.;
if tobacco_composite>0 then any_tobacco=1;
else if tobacco_composite=0 then any_tobacco=0;
else if tobacco_composite=. then any_tobacco=.;
if tobacco_composite=1 or tobacco_composite =0 then poly_tobacco=0;
else if tobacco_composite>1 then poly_tobacco=1;
else if tobacco_composite=. then poly_tobacco=.;
run;
proc freq data=work.merged8;
table any_substance poly_substance any_tobacco poly_tobacco cigs_2lvl
poly_tobacco*ecigs_2lvl;
run;
data work.merged9; set work.merged8;
if cigs_2lvl=1 and poly_tobacco=1 then cigs_poly=1;
else if cigs_2lvl=0 and poly_tobacco=1 or cigs_2lvl=1 and poly_tobacco=0 or
cigs_2lvl=0 and poly_tobacco=0 then cigs_poly=0;
else if cigs_2lvl=. or poly_tobacco=. then cigs_poly=.;
if hookah_2lvl=1 and poly_tobacco=1 then hookah_poly=1;
else if hookah_2lvl=0 and poly_tobacco=1 or hookah_2lvl=1 and poly_tobacco=0
or hookah_2lvl=0 and poly_tobacco=0 then hookah_poly=0;
else if hookah_2lvl=. or poly_tobacco=. then hookah_poly=.;
if cigar_2lvl=1 and poly_tobacco=1 then cigar_poly=1;
else if cigar_2lvl=0 and poly_tobacco=1 or cigar_2lvl=1 and poly_tobacco=0 or
cigar_2lvl=0 and poly_tobacco=0 then cigar_poly=0;
else if cigar_2lvl=. or poly_tobacco=. then cigar_poly=.;
if smkless_2lvl=1 and poly_tobacco=1 then smkless_poly=1;
else if smkless_2lvl=0 and poly_tobacco=1 or smkless_2lvl=1 and
poly_tobacco=0 or smkless_2lvl=0 and poly_tobacco=0 then smkless_poly=0;
else if smkless_2lvl=. or poly_tobacco=. then smkless_poly=.;
if ecigs_2lvl=1 and poly_tobacco=1 then ecigs_poly=1;
else if ecigs_2lvl=1 and poly_tobacco=0 or ecigs_2lvl=0 and poly_tobacco=1 or
ecigs_2lvl=0 and poly_tobacco=0 then ecigs_poly=0;
else if ecigs_2lvl=. or poly_tobacco=. then ecigs_poly=.;
run;
proc freq data=work.merged9;
```

```
table cigs_poly hookah_poly cigar_poly smkless_poly ecigs_poly;
run;

*/keep only needed variables*/;
data work.merged10; set work.merged9;
keep
NQ1 NQ8A1 NQ8A2 NQ8A3 NQ8A4 NQ8A5 NQ8A6 NQ8A7 NQ8A8 NQ8A9 NQ8B1 NQ8B2 NQ8B3
NQ8B4 NQ8B5 NQ8B6 NQ8B7 NQ8B8 NQ9A1 NQ9A2 NQ9A3 NQ9A4 NQ9A5 NQ9A6 NQ9A7
NQ9A8 NQ9A9 NQ9B1 NQ9B2 NQ9B3 NQ9B4 NQ9B5 NQ9B6 NQ9B7 NQ9B8 NQ10 NQ11 NQ12
NQ13 NQ14A NQ14B NQ17A NQ17B NQ17C NQ18A NQ18B NQ18C NQ18D NQ18E NQ19 NQ31A1
NQ31A2 NQ31A3 NQ31A4 NQ31A5 NQ31A6 NQ31A7 NQ31A8 NQ31B1 NQ31B2 NQ31B3 NQ31B4
NQ31B5 NQ31B6 NQ31B7 NQ32 NQ33A NQ33B NQ33C NQ33D NQ33E NQ33F NQ33G NQ33H
NQ33I NQ33J NQ33K NQ33L NQ37 NQ42 NQ43 NQ44A NQ44B NQ44C NQ44D NQ46 NQ51 NQ52
NQ53 NQ55 NQ59 NQ63 BAC RBAC1 RBAC2 BMI RBMI PUBPRIV TYPE REGION SCHOOLID
Gender Study_Semester Live_recode SIZE_recode LOCALE_recode Sex_or Race
Cigs_2lvl Hookah_2lvl Cigar_2lvl Smkless_2lvl Alcohol_2lvl Marij_2lvl
Ecigs_2lvl
Cigs_3lvl Hookah_3lvl Cigar_3lvl Smkless_3lvl Alcohol_3lvl Marij_3lvl
Ecigs_3lvl Cigs_4lvl Hookah_4lvl Cigar_4lvl Smkless_4lvl Alcohol_4lvl
Marij_4lvl Ecigs_4lvl
Cigs_ever Hookah_ever Cigar_ever Smkless_ever Alcohol_ever Marij_ever
Ecigs_ever BINGE_2lvl BINGE_3lvl Perc_Cigs_2lvl Perc_Hookah_2lvl
Perc_Cigar_2lvl Perc_Smkless_2lvl
Perc_Alcohol_2lvl Perc_Marij_2lvl Perc_Ecigs_2lvl Perc_Cigs_3lvl
Perc_Hookah_3lvl Perc_Cigar_3lvl Perc_Smkless_3lvl Perc_Alcohol_3lvl
Perc_Marij_3lvl Perc_Ecigs_3lvl
Perc_Cigs_4lvl Perc_Hookah_4lvl Perc_Cigar_4lvl Perc_Smkless_4lvl
Perc_Alcohol_4lvl Perc_Marij_4lvl Perc_Ecigs_4lvl Perc_Cigs_ever
Perc_Hookah_ever Perc_Cigar_ever
Perc_Smkless_ever Perc_Alcohol_ever Perc_Marij_ever Perc_Ecigs_ever
use_composite perc_composite tobacco_composite Perc_tob_composite
any_substance poly_substance any_tobacco
poly_tobacco cigs_poly hookah_poly cigar_poly smkless_poly ecigs_poly;
run;
PROC EXPORT DATA= WORK.MERGED10
            OUTFILE= "C:\Users\micha\Dropbox\1. Dissertation\4. Paper
3\Merged Analytical Dataset\NCHA National data 2009-2016 merged.sav"
            DBMS=SPSS REPLACE; RUN;


PROC IMPORT OUT= WORK.trend
            DATAFILE= "C:\Users\micha\Dropbox\1. Dissertation\4. Paper
3\Merged Analytical Dataset\NCHA National data 2009-2016 merged.sav"
            DBMS=SPSS REPLACE;
RUN;
proc contents data=work.trend order=varnum;run;

proc freq data=work.trend;
table schoolid study_semester;run;
proc freq data=work.trend;
Table cigs_poly hookah_poly cigar_poly smkless_poly ecigs_poly;run;

*/ changing from study semester to study academic year*/;
data work.trend_combined;set work.trend;
if study_semester=1 then study_year=1;
else if study_semester=2 then study_year=1;
```

```
else if study_semester=3 then study_year=2;
else if study_semester=4 then study_year=2;
else if study_semester=6 then study_year=3;
else if study_semester=7 then study_year=3;
else if study_semester=8 then study_year=4;
else if study_semester=9 then study_year=4;
else if study_semester=10 then study_year=5;
else if study_semester=11 then study_year=5;
else if study_semester=12 then study_year=6;
else if study_semester=13 then study_year=6;
else if study_semester=14 then study_year=7;
else if study_semester=15 then study_year=7;
else if study_semester=16 then study_year=8;run;

*/ create data set for linear regressions without the last semester*/;
data work.trend_combined1; set work.trend_combined;
if study_year=8 then delete;run;

*/ Demographic Frequencies by study semester*/;
proc freq data=work.trend_combined;
Table study_year;run;
proc freq data=work.trend_combined;
Table (gender race Sex_or live_recode NQ51 REgion NQ59 NQ55 NQ63 PUBPRIV
LOCALE_recode SIZE_recode) *study_year;run;
proc means data=work.trend_combined;
var nq46;
run;
proc means data=work.trend_combined;
var nq46;by study_year;
run;

*/ Substance use 3 level Frequencies by study academic year*/;
proc freq data=work.trend_combined;
Table (cigs_3lvl hookah_3lvl cigar_3lvl smkless_3lvl ecigs_3lvl alcohol_3lvl
binge_3lvl marij_3lvl)*study_year;run;

*/ Substance use 2 level Frequencies by study academic year with trend
test*/;
proc freq data=work.trend_combined;
Table (cigs_2lvl hookah_2lvl cigar_2lvl smkless_2lvl ecigs_2lvl alcohol_2lvl
binge_2lvl marij_2lvl)*study_year/trend;run;

*/ simple linear regression between substance use and study year */;
proc reg data=work.trend_combined1;
model cigs_2lvl=study_year;run;quit;
proc reg data=work.trend_combined1;
model hookah_2lvl=study_year;run;quit;
proc reg data=work.trend_combined1;
model cigar_2lvl=study_year;run;quit;
proc reg data=work.trend_combined1;
model smkless_2lvl=study_year;run;quit;
proc reg data=work.trend_combined1;
model alcohol_2lvl=study_year;run;quit;
proc reg data=work.trend_combined1;
model binge_2lvl=study_year;run;quit;
proc reg data=work.trend_combined1;
model marij_2lvl=study_year;run;quit;
```

```
*/ Substance use ever Frequencies by study academic year with trend test*/;
proc freq data=work.trend_combined;
Table (cigs_ever hookah_ever cigar_ever smkless_ever ecigs_ever alcohol_ever
marij_ever)*study_year/trend;run;

*/ simple linear regression between ever substance use and study year */;
proc reg data=work.trend_combined1;
model cigs_ever=study_year;run;quit;
proc reg data=work.trend_combined1;
model hookah_ever=study_year;run;quit;
proc reg data=work.trend_combined1;
model cigar_ever=study_year;run;quit;
proc reg data=work.trend_combined1;
model smkless_ever=study_year;run;quit;
proc reg data=work.trend_combined1;
model alcohol_ever=study_year;run;quit;
proc reg data=work.trend_combined1;
model marij_ever=study_year;run;quit;

*/ Perceived peer current Substance use  Frequencies by study academic year
with trend test*/;
proc freq data=work.trend_combined;
Table (Perc_cigs_2lvl Perc_hookah_2lvl Perc_cigar_2lvl Perc_smkless_2lvl
Perc_ecigs_2lvl Perc_alcohol_2lvl Perc_marij_2lvl)*study_year/trend;run;

*/ simple linear regression between Perceived peer current substance use and
study year */;
proc reg data=work.trend_combined1;
model Perc_cigs_2lvl=study_year;run;quit;
proc reg data=work.trend_combined1;
model Perc_hookah_2lvl=study_year;run;quit;
proc reg data=work.trend_combined1;
model Perc_cigar_2lvl=study_year;run;quit;
proc reg data=work.trend_combined1;
model Perc_smkless_2lvl=study_year;run;quit;
proc reg data=work.trend_combined1;
model Perc_alcohol_2lvl=study_year;run;quit;
proc reg data=work.trend_combined1;
model Perc_marij_2lvl=study_year;run;quit;

*/BY
GENDER*/******************************************************************;
proc sort data=work.trend_combined;
by Gender study_year;run;
proc sort data=work.trend_combined1;
by Gender study_year;run;
proc freq data=work.trend_combined;
Table (cigs_3lvl hookah_3lvl cigar_3lvl smkless_3lvl ecigs_3lvl alcohol_3lvl
binge_3lvl marij_3lvl)*study_year/trend;
by Gender;run;
proc freq data=work.trend_combined;
Table (cigs_2lvl hookah_2lvl cigar_2lvl smkless_2lvl ecigs_2lvl alcohol_2lvl
binge_2lvl marij_2lvl)*study_year/trend;
by Gender;run;
proc reg data=work.trend_combined1;
model cigs_2lvl=study_year;
```

```
by Gender;run;quit;
proc reg data=work.trend_combined1;
model hookah_2lvl=study_year;
by Gender;run;quit;
proc reg data=work.trend_combined1;
model cigar_2lvl=study_year;
by Gender;run;quit;
proc reg data=work.trend_combined1;
model smkless_2lvl=study_year;
by Gender;run;quit;
proc reg data=work.trend_combined1;
model alcohol_2lvl=study_year;
by Gender;run;quit;
proc reg data=work.trend_combined1;
model binge_2lvl=study_year;
by Gender;run;quit;
proc reg data=work.trend_combined1;
model marij_2lvl=study_year;
by Gender;run;quit;

*/ Substance use ever Frequencies by study academic year with trend test*/;
proc freq data=work.trend_combined;
Table (cigs_ever hookah_ever cigar_ever smkless_ever ecigs_ever alcohol_ever
marij_ever)*study_year/trend;
by Gender;run;

*/ simple linear regression between ever substance use and study year */;
proc reg data=work.trend_combined1;
model cigs_ever=study_year;
by Gender;run;quit;
proc reg data=work.trend_combined1;
model hookah_ever=study_year;
by Gender;run;quit;
proc reg data=work.trend_combined1;
model cigar_ever=study_year;
by Gender;run;quit;
proc reg data=work.trend_combined1;
model smkless_ever=study_year;
by Gender;run;quit;
proc reg data=work.trend_combined1;
model alcohol_ever=study_year;
by Gender;run;quit;
proc reg data=work.trend_combined1;
model marij_ever=study_year;
by Gender;run;quit;

*/ Perceived peer current Substance use  Frequencies by study academic year
with trend test*/;
proc sort data=work.trend_combined;
by Gender study_year;run;
proc freq data=work.trend_combined;
Table (Perc_cigs_2lvl Perc_hookah_2lvl Perc_cigar_2lvl Perc_smkless_2lvl
Perc_ecigs_2lvl Perc_alcohol_2lvl Perc_marij_2lvl)*study_year/chisq;
by Gender;run;

*/ simple linear regression between Perceived peer current substance use and
study year */;
```

```
proc reg data=work.trend_combined1;
model Perc_cigs_2lvl=study_year;
by Gender;run;quit;
proc reg data=work.trend_combined1;
model Perc_hookah_2lvl=study_year;
by Gender;run;quit;
proc reg data=work.trend_combined1;
model Perc_cigar_2lvl=study_year;
by Gender;run;quit;
proc reg data=work.trend_combined1;
model smkless_2lvl=study_year;
by Gender;run;quit;
proc reg data=work.trend_combined1;
model Perc_alcohol_2lvl=study_year;
by Gender;run;quit;
proc reg data=work.trend_combined1;
model Perc_marij_2lvl=study_year;
by Gender;run;quit;

*/Poly use
behaviors*/*****************************************************;
*/ Composite Tobacco use  Frequencies by study academic year with trend
test*/;
proc freq data=work.trend_combined;
Table tobacco_composite*study_year/chisq;run;
proc reg data=work.trend_combined;
model tobacco_composite=study_year;run;quit;
proc freq data=work.trend_combined;
Table tobacco_composite*study_year/chisq;
by Gender; run;
proc reg data=work.trend_combined;
model tobacco_composite=study_year;
by Gender;run;quit;
proc means data=work.trend_combined;
var tobacco_composite;
by gender study_year ;
run;
proc freq data=work.trend_combined;
Table tobacco_composite*study_year/chisq;run;
proc reg data=work.trend_combined1;
model tobacco_composite=study_year;run;quit;
proc freq data=work.trend_combined;
Table tobacco_composite*study_year/chisq;
by Gender; run;
proc reg data=work.trend_combined1;
model tobacco_composite=study_year;
by Gender;run;quit;
proc reg data=work.trend_combined1;
model cigs_poly=study_year;
by Gender;run;quit;
proc reg data=work.trend_combined1;
model hookah_poly=study_year;
by Gender;run;quit;
proc reg data=work.trend_combined1;
model cigar_poly=study_year;
by Gender;run;quit;
proc reg data=work.trend_combined1;
```

```
model smkless_poly=study_year;
by Gender;run;quit;
proc reg data=work.trend_combined1;
model cigs_poly=study_year;
run;quit;
proc reg data=work.trend_combined1;
model hookah_poly=study_year;
run;quit;
proc reg data=work.trend_combined1;
model cigar_poly=study_year;
run;quit;
proc reg data=work.trend_combined1;
model smkless_poly=study_year;
run;quit;

*/Tobacco product use among Poly-tobacc users*/;
proc freq data=work.trend_combined;
Table (cigs_poly hookah_poly cigar_poly smkless_poly
ecigs_poly)*study_year;run;

data work.trend_poly; set work.trend_combined;
if  tobacco_composite=0 or tobacco_composite=1 then delete;run;
data work.trend_poly1; set work.trend_combined1;
if  tobacco_composite=0 or tobacco_composite=1 then delete;run;
data work.trend_poly2; set work.trend_combined1;
if  tobacco_composite<2 then poly_2lvl=0;
else if tobacco_composite>=2 then poly_2lvl=1;
if tobacco_composite=1 then single_product_2lvl=1;
else if tobacco_composite>1 or tobacco_composite<1 then
single_product_2lvl=0;
run;
proc sort data=work.trend_poly2;
by Gender study_year;run;
proc reg data=work.trend_poly2;
model poly_2lvl=study_year;
run;quit;
proc reg data=work.trend_poly2;
model poly_2lvl=study_year;
by gender;
run;quit;
proc reg data=work.trend_poly2;
model single_product_2lvl=study_year;
run;quit;
proc reg data=work.trend_poly2;
model single_product_2lvl=study_year;
by gender;
run;quit;
proc freq data=work.trend_poly;
table study_year;
run;
proc freq data=work.trend_poly;
table gender*study_year;
run;
proc freq data=work.trend_poly;
table (cigs_2lvl hookah_2lvl cigar_2lvl smkless_2lvl ecigs_2lvl)*study_year;
run;
proc sort data=work.trend_poly;
```

```
by Gender study_year;run;
proc sort data=work.trend_poly1;
by Gender study_year;run;
proc freq data=work.trend_poly;
table (cigs_2lvl hookah_2lvl cigar_2lvl smkless_2lvl
ecigs_2lvl)*study_year/chisq;
by gender;
run;
proc reg data=work.trend_poly1;
model cigs_poly=study_year;
run;quit;
proc reg data=work.trend_poly1;
model hookah_poly=study_year;
run;quit;
proc reg data=work.trend_poly1;
model cigar_poly=study_year;
run;quit;
proc reg data=work.trend_poly1;
model smkless_poly=study_year;
run;quit;
proc reg data=work.trend_poly1;
model cigs_poly=study_year;
by Gender;run;quit;
proc reg data=work.trend_poly1;
model hookah_poly=study_year;
by Gender;run;quit;
proc reg data=work.trend_poly1;
model cigar_poly=study_year;
by Gender;run;quit;
proc reg data=work.trend_poly1;
model smkless_poly=study_year;
by Gender;run;quit;

**/Logistic Regression: percerived peer behaviors and self-reported
behaviors*/**;
proc logistic data=work.trend_combined;
model perc_cigs_2lvl(event='1')=cigs_2lvl SCHOOLID study_year NQ46;
run;
proc logistic data=work.trend_combined;
model perc_cigs_2lvl(event='1')=cigs_2lvl SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
model perc_hookah_2lvl(event='1')=hookah_2lvl SCHOOLID study_year NQ46;
run;
proc logistic data=work.trend_combined;
model perc_hookah_2lvl(event='1')=hookah_2lvl SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
model perc_cigar_2lvl(event='1')=cigar_2lvl SCHOOLID study_year NQ46;
run;
proc logistic data=work.trend_combined;
model perc_cigar_2lvl(event='1')=cigar_2lvl SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
```

```
model perc_smkless_2lvl(event='1')=smkless_2lvl SCHOOLID study_year NQ46;
run;
proc logistic data=work.trend_combined;
model perc_smkless_2lvl(event='1')=smkless_2lvl SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
model perc_ecigs_2lvl(event='1')=ecigs_2lvl SCHOOLID study_year NQ46;
run;
proc logistic data=work.trend_combined;
model perc_ecigs_2lvl(event='1')=ecigs_2lvl SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
model perc_alcohol_2lvl(event='1')=alcohol_2lvl SCHOOLID study_year NQ46;
run;
proc logistic data=work.trend_combined;
model perc_alcohol_2lvl(event='1')=alcohol_2lvl SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
model perc_marij_2lvl(event='1')=marij_2lvl SCHOOLID study_year NQ46;
run;
proc logistic data=work.trend_combined;
model perc_marij_2lvl(event='1')=marij_2lvl SCHOOLID study_year NQ46;
by gender;
run;

**/Logistic Regression: poly-use behaviors and demographics*/**;
*/Race*/;
proc logistic data=work.trend_combined;
class Race (ref='1');
model cigs_poly(event='1')= Race SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class Race (ref='1');
model hookah_poly(event='1')= Race SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class Race (ref='1');
model cigar_poly(event='1')= Race SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class Race (ref='1');
model Smkless_poly(event='1')= Race SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class Race (ref='1');
model ecigs_poly(event='1')= Race SCHOOLID study_year NQ46;
by gender;
run;

*/Sex_or*/;
```

```
proc logistic data=work.trend_combined;
class Sex_or (ref='1');
model cigs_poly(event='1')= Sex_or SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class Sex_or (ref='1');
model hookah_poly(event='1')= Sex_or SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class Sex_or (ref='1');
model cigar_poly(event='1')= Sex_or SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class Sex_or (ref='1');
model Smkless_poly(event='1')= Sex_or SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class Sex_or (ref='1');
model ecigs_poly(event='1')= Sex_or SCHOOLID study_year NQ46;
by gender;
run;

*/Live on campus?*/;
proc logistic data=work.trend_combined;
class live_recode (ref='1 live on campus');
model cigs_poly(event='1')= live_recode SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class live_recode (ref='1 live on campus');
model hookah_poly(event='1')= live_recode SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class live_recode (ref='1 live on campus');
model cigar_poly(event='1')= live_recode SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class live_recode (ref='1 live on campus');
model Smkless_poly(event='1')= live_recode SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class live_recode (ref='1 live on campus');
model ecigs_poly(event='1')= live_recode SCHOOLID study_year NQ46;
by gender;
run;

*/Year in school*/;
proc logistic data=work.trend_combined;
class NQ51 (ref='1st year undergraduate');
model cigs_poly(event='1')= NQ51 SCHOOLID study_year NQ46;
```

```
by gender;
run;
proc logistic data=work.trend_combined;
class NQ51 (ref='1st year undergraduate');
model hookah_poly(event='1')= NQ51 SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class NQ51 (ref='1st year undergraduate');
model cigar_poly(event='1')= NQ51 SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class NQ51 (ref='1st year undergraduate');
model Smkless_poly(event='1')= NQ51 SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class NQ51 (ref='1st year undergraduate');
model ecigs_poly(event='1')= NQ51 SCHOOLID study_year NQ46;
by gender;
run;

*/Greek*/;
proc logistic data=work.trend_combined;
class NQ59 (ref='No');
model cigs_poly(event='1')= NQ59 SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class NQ59 (ref='No');
model hookah_poly(event='1')= NQ59 SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class NQ59 (ref='No');
model cigar_poly(event='1')= NQ59 SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class NQ59 (ref='No');
model Smkless_poly(event='1')= NQ59 SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class NQ59 (ref='No');
model ecigs_poly(event='1')= NQ59 SCHOOLID study_year NQ46;
by gender;
run;

*/GPA*/;
proc logistic data=work.trend_combined;
class NQ63 (ref='A');
model cigs_poly(event='1')= NQ63 SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
```

```
class NQ63 (ref='A');
model hookah_poly(event='1')= NQ63 SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class NQ63 (ref='A');
model cigar_poly(event='1')= NQ63 SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class NQ63 (ref='A');
model Smkless_poly(event='1')= NQ63 SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class NQ63 (ref='A');
model ecigs_poly(event='1')= NQ63 SCHOOLID study_year NQ46;
by gender;
run;

*/Region*/;
proc logistic data=work.trend_combined;
class Region (ref='Northeast');
model cigs_poly(event='1')= Region SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class Region (ref='Northeast');
model hookah_poly(event='1')= Region SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class Region (ref='Northeast');
model cigar_poly(event='1')= Region SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class Region (ref='Northeast');
model Smkless_poly(event='1')= Region SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class Region (ref='Northeast');
model ecigs_poly(event='1')= Region SCHOOLID study_year NQ46;
by gender;
run;

*/PubPriv*/;
proc logistic data=work.trend_combined;
class PubPriv (ref='Public');
model cigs_poly(event='1')= PubPriv SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class PubPriv (ref='Public');
model hookah_poly(event='1')= PubPriv SCHOOLID study_year NQ46;
by gender;
```

```
run;
proc logistic data=work.trend_combined;
class PubPriv (ref='Public');
model cigar_poly(event='1')= PubPriv SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class PubPriv (ref='Public');
model Smkless_poly(event='1')= PubPriv SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class PubPriv (ref='Public');
model ecigs_poly(event='1')= PubPriv SCHOOLID study_year NQ46;
by gender;
run;

*/size_recode*/;
proc freq data=work.trend_combined;
table size_recode;run;
proc logistic data=work.trend_combined;
class size_recode (ref='1 small campus <=5k');
model cigs_poly(event='1')= size_recode SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class size_recode (ref='1 small campus <=5k');
model hookah_poly(event='1')= size_recode SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class size_recode (ref='1 small campus <=5k');
model cigar_poly(event='1')= size_recode SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class size_recode (ref='1 small campus <=5k');
model Smkless_poly(event='1')= size_recode SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class size_recode (ref='1 small campus <=5k');
model ecigs_poly(event='1')= size_recode SCHOOLID study_year NQ46;
by gender;
run;

*/poly use with marij and alcohol*/;
proc logistic data=work.trend_combined;
model cigs_poly(event='1')= alcohol_2lvl SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
model cigs_poly(event='1')= binge_2lvl SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
model cigs_poly(event='1')= marij_2lvl SCHOOLID study_year NQ46;
```

```
by gender;
run;
proc logistic data=work.trend_combined;
model hookah_poly(event='1')= alcohol_2lvl SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
model hookah_poly(event='1')= binge_2lvl SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
model hookah_poly(event='1')= marij_2lvl SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
model cigar_poly(event='1')= alcohol_2lvl SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
model cigar_poly(event='1')= binge_2lvl SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
model cigar_poly(event='1')= marij_2lvl SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
model smkless_poly(event='1')= alcohol_2lvl SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
model smkless_poly(event='1')= binge_2lvl SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
model smkless_poly(event='1')= marij_2lvl SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
model ecigs_poly(event='1')= alcohol_2lvl SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
model ecigs_poly(event='1')= binge_2lvl SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
model ecigs_poly(event='1')= marij_2lvl SCHOOLID study_year NQ46;
by gender;
run;

*/Percevied tobacco use and polyuse*/;
proc logistic data=work.trend_combined;
class perc_tob_composite (ref="0");
model cigs_poly(event='1')= perc_tob_composite SCHOOLID study_year NQ46;
by gender;
run;
```

```
proc logistic data=work.trend_combined;
class perc_tob_composite (ref="0");
model hookah_poly(event='1')= perc_tob_composite SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class perc_tob_composite (ref="0");
model cigar_poly(event='1')= perc_tob_composite SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class perc_tob_composite (ref="0");
model smkless_poly(event='1')= perc_tob_composite SCHOOLID study_year NQ46;
by gender;
run;
proc logistic data=work.trend_combined;
class perc_tob_composite (ref="0");
model ecigs_poly(event='1')= perc_tob_composite SCHOOLID study_year NQ46;
by gender;
run;
```

Appendix 3.1. MPLUS example code for the Full sample examining 2 latent classes

```
Data:
   File is "C:\Users\sawdeymd\Documents\1. Dissertation\Paper 2\Data\Paper 2 Recode.dat";
Variable:
   Names =RNQ47 BINGE_3lvl NQ8A1_3lvl NQ8A2_3lvl NQ8A3_3lvl NQ8A5_3lvl
   NQ8A6_3lvl NQ8A10_3lvl id;
   Usevariables = BINGE_3lvl NQ8A1_3lvl NQ8A2_3lvl NQ8A3_3lvl NQ8A5_3lvl
   NQ8A6_3lvl NQ8A10_3lvl;
   IDVARIABLE IS id;
   CATEGORICAL = NQ8A1_3lvl NQ8A2_3lvl NQ8A3_3lvl NQ8A5_3lvl NQ8A6_3lvl
   NQ8A10_3lvl BINGE_3lvl;
  Missing are .;
  classes= c(2);
Analysis:
  type=mixture;
  miterations=8000;
  STARTS = 4000 1000;
  LRTSTARTS= 0 0 2000 300;
OUTPUT: TECH11 TECH14;
```

Appendix 3.2 Code for SAS for Chapter 3

```
libname LCA_post "C:\Users\micha\Dropbox\1. Dissertation\Paper
2\Analyses\Post-LCA analysis\2. Merged LCA data with Original Data";
OPTIONS FMTSEARCH=(PostLCA.formats);

proc import out=work.LCAALLclass
 datafile="C:\Users\micha\Dropbox\1. Dissertation\Paper 2\Analyses\Post-LCA
analysis\1. Outputted LCA Data to be merged\ALL7.xlsx"
 DBMS = XLSX;
run;

proc import out=work.LCAMalesclass
 datafile="C:\Users\micha\Dropbox\1. Dissertation\Paper 2\Analyses\Post-LCA
analysis\1. Outputted LCA Data to be merged\MALE6.xlsx"
 DBMS = XLSX;
run;
proc import out=work.LCAFemalesclass
 datafile="C:\Users\micha\Dropbox\1. Dissertation\Paper 2\Analyses\Post-LCA
analysis\1. Outputted LCA Data to be merged\FEMA6.xlsx"
 DBMS = XLSX;
run;

proc catalog catalog = LCA_Post.formats;
  copy out = work.formats;
  run;
quit;
data work.LCAall_Merged;
merge LCA_post.original work.LCAallclass;
by id;run;

DATA work.original_Female; set LCA_post.original;
if  RNQ47 = 2 then delete;run;
DATA work.original_male; set  LCA_post.original;
if  RNQ47 = 1 then delete;run;

data work.LCA_Female_Merged;
merge work.original_Female work.LCAFemalesclass;
by id;run;

data Work.LCA_Male_Merged;
merge work.original_male work.LCAMalesclass;
by id;run;

libname LCAFinal "C:\Users\micha\Dropbox\1. Dissertation\Paper
2\Analyses\Post-LCA analysis\3. Analytic Dataset";
proc catalog catalog = work.formats;
```

```
  copy out = LCAFinal.formats;
  run;
quit;
options fmtsearch = (work, library, SASdata);
data LCAFinal.LCA_All_Merged;
merge work.LCAall_Merged work.LCA_Female_Merged work.LCA_Male_Merged;
by id;run;
*/DO NOT CHANGE*/;
libname PostLCA "C:\Users\micha\Dropbox\1. Dissertation\Paper
2\Analyses\Post-LCA analysis\3. Analytic Dataset";
OPTIONS FMTSEARCH=(PostLCA.formats);
data work.LCA; set PostLCA.lca_all_merged;run;
*/DO NOT CHANGE*/;
proc contents data=work.LCA order=varnum; run;

*/remove 3 individuals without classes*/;
proc freq data=work.lca;
table CLASS_All CLASS_FEMA CLASS_MALE NQ63;run;

data work.lca1;set work.lca;
if CLASS_all =. then delete;
if size = 1 then size_r=1;
else if size=2 then size_r=1;
else if size=3 then size_r=2;
else if size=4 then size_r=2;
else if size=5 then size_r=2;
if locale = 1 then locale_r=1;
else if locale=2 then locale_r=1;
else if locale=3 then locale_r=2;
else if locale=4 then locale_r=2;
else if locale=5 then locale_r=2;
if NQ63 = 5 then NQ63=.;
label nq58_recode = "Housing";
label nq59 = "greek";
run;
proc format;
value locale_r
      1="small 0-50k"
      2= "medium/large >50k";
value size_r
      1="small 0-5k"
      2= "medium/large >5k";
value nq58_recode
      1= "on campus"
      2= "off campus";run;
proc freq data=work.lca1;
table CLASS_All class_male class_fema;run;


*/Frequencies Demographics*/;
Proc univariate data=work.LCA1;
var nq46;run;
Proc freq data=work.LCA1;
table NQ46 RNQ47 RACE NQ51 region pubpriv locale_r size_r nq58_recode nq59
NQ63;
format size_r size_r. locale_r locale_r. nq58_recode nq58_recode.;
run;
```

```
proc sort data=work.LCA1;
by RNQ47;run;
Proc freq data=work.LCA1;
table RNQ47* (NQ46 RNQ47 RACE NQ51 region pubpriv locale_r size_r nq58_recode
nq59 NQ63)/chisq;
format size_r size_r. locale_r locale_r. nq58_recode nq58_recode.; run;
Proc univariate data=work.LCA1;
var nq46;
by RNQ47;run;
Proc freq data=work.LCA1;
table NQ46 RNQ47 RACE NQ51 region pubpriv locale_r size_r nq58_recode nq59
NQ63;
by RNQ47;
format size_r size_r. locale_r locale_r. nq58_recode nq58_recode.; run;


*/Frequencies Substances*/;
Proc freq data=work.LCA1;
table NQ8A1_3lvl NQ8A2_3lvl NQ8A3_3lvl NQ8A10_3lvl NQ8A5_3lvl BINGE_3lvl
NQ8A6_3lvl ;
run;
proc sort data=work.LCA1;
by RNQ47;run;
Proc freq data=work.LCA1;

table  RNQ47*(NQ8A1_3lvl NQ8A2_3lvl NQ8A3_3lvl NQ8A10_3lvl NQ8A5_3lvl
BINGE_3lvl NQ8A6_3lvl)/chisq ;
run;

/* Determining the number of behaviors*/;
data  work.LCA2 ;
set work.LCA1 ;
usecomposite = sum(NQ8A1_2lvl + NQ8A2_2lvl + NQ8A3_2lvl + NQ8A10_2lvl +
NQ8A5_2lvl + BINGE_2lvl + NQ8A6_2lvl);
run;
proc freq data=work.LCA2;
table usecomposite;run;
proc freq data=work.LCA2;
table RNQ47*usecomposite/chisq;run;
proc freq data=work.LCA2;
table usecomposite;
by RNQ47;run;
proc sort data=work.LCA2;
by CLASS_ALL;run;
proc freq data=work.LCA2;
table usecomposite;
by CLASS_ALL;run;
proc sort data=work.LCA2;
by CLASS_FEMA;run;
proc freq data=work.LCA2;
table usecomposite;
by CLASS_FEMA;run;
proc sort data=work.LCA2;
by CLASS_MALE;run;
proc freq data=work.LCA2;
table usecomposite;
by CLASS_MALE;run;
```

```
/*Poly and dual substance use*/;
data work.LCA3; set work.LCA2;
if usecomposite=1 or usecomposite=0 then dual=0;
else if usecomposite=2 then dual=1;
else if usecomposite=. then dual=.;run;
data work.LCA4; set work.LCA3;
if usecomposite=2 or usecomposite=1 or usecomposite =0 then poly=0;
else if usecomposite>2 then poly=1;
else if usecomposite=. then poly=.;run;
proc freq data=work.LCA4;
table poly dual;run;
proc freq data=work.LCA4;
table RNQ47*(poly dual)/chisq;run;
proc freq data=work.LCA4;
by RNQ47;
table poly dual;run;

data  work.LCA5;set work.LCA4 ;
if NQ8A1_2lvl=1 or NQ8A1_2lvl=1 or NQ8A3_2lvl=1 or  NQ8A10_2lvl=1 then
singletobacco=1;
else if NQ8A1_2lvl=0 and NQ8A3_2lvl=0 and NQ8A10_2lvl=0 and NQ8A2_2lvl=0 then
singletobacco=0;
else if NQ8A1_2lvl=. and NQ8A3_2lvl=. and NQ8A10_2lvl=. and NQ8A2_2lvl=. then
singletobacco=.;
if NQ8A1_2lvl=1 and NQ8A3_2lvl=1 then dualtobacco=1;
else if NQ8A1_2lvl=1 and NQ8A10_2lvl=1 then dualtobacco=1;
else if NQ8A1_2lvl=1 and NQ8A2_2lvl=1 then dualtobacco=1;
else if NQ8A3_2lvl=1 and NQ8A10_2lvl=1 then dualtobacco=1;
else if NQ8A3_2lvl=1 and NQ8A2_2lvl=1 then dualtobacco=1;
else if NQ8A2_2lvl=1 and NQ8A10_2lvl=1 then dualtobacco=1;
else if NQ8A1_2lvl=0 or NQ8A3_2lvl=0 or NQ8A10_2lvl=0 or NQ8A2_2lvl=0 then
dualtobacco=0;
if NQ8A1_2lvl=. or NQ8A10_2lvl=. or NQ8A2_2lvl=. or NQ8A3_2lvl=. then
dualtobacco=.;run;

data  work.LCA6;set work.LCA5 ;
if NQ8A1_2lvl=1 and NQ8A3_2lvl=1 and NQ8A10_2lvl=1  then polytobacco=1;
else if NQ8A1_2lvl=1 and NQ8A3_2lvl=1 and NQ8A2_2lvl=1  then polytobacco=1;
else if NQ8A1_2lvl=1 and NQ8A2_2lvl=1 and NQ8A10_2lvl=1  then polytobacco=1;
else if NQ8A3_2lvl=1 and NQ8A2_2lvl=1 and NQ8A10_2lvl=1 then polytobacco=1;
else if NQ8A1_2lvl=0 or NQ8A3_2lvl=0 or NQ8A10_2lvl=0 or NQ8A2_2lvl=0  then
polytobacco=0;
if NQ8A1_2lvl=. or NQ8A10_2lvl=. or NQ8A2_2lvl=. or NQ8A3_2lvl=. then
polytobacco=.;run;

proc freq data=work.LCA6;
table RNQ47*(dualtobacco polytobacco singletobacco)/chisq;
run;
proc freq data=work.LCA6;
by RNQ47;
table singletobacco dualtobacco polytobacco;
run;
proc freq data=work.LCA6;
table singletobacco dualtobacco polytobacco;
run;
```

```
data work.LCA7;set work.LCA6;
if singletobacco=1 and NQ8A5_2lvl=1 then STalcohol=1;
else if singletobacco=0 or NQ8A5_2lvl=0 then STalcohol=0;
if singletobacco=. or NQ8A5_2lvl=. then STalcohol=.;
if dualtobacco=1 and NQ8A5_2lvl=1 then DTalcohol=1;
else if dualtobacco=0 or NQ8A5_2lvl=0 then DTalcohol=0;
if dualtobacco=. or NQ8A5_2lvl=. then DTalcohol=.;
run;
data work.LCA8;set work.LCA7;
if singletobacco=1 and NQ8A6_2lvl=1 then STmarij=1;
else if singletobacco=0 or NQ8A6_2lvl=0 then STmarij=0;
 if singletobacco=. or NQ8A6_2lvl=. then STmarij=.;
if dualtobacco=1 and NQ8A6_2lvl=1 then DTmarij=1;
else if dualtobacco=0 or NQ8A6_2lvl=0 then DTmarij=0;
 if dualtobacco=. or NQ8A6_2lvl=. then DTmarij=.;
run;
data work.LCA9;set work.LCA8;
if singletobacco=1 and BINGE_2lvl=1 then STbinge=1;
else if singletobacco=0 or BINGE_2lvl=0 then STbinge=0;
if singletobacco=. or BINGE_2lvl=. then STbinge=.;
if dualtobacco=1 and BINGE_2lvl=1 then DTbinge=1;
else if dualtobacco=0 or BINGE_2lvl=0 then DTbinge=0;
if dualtobacco=. or BINGE_2lvl=. then DTbinge=.;
run;

proc freq data=work.LCA9;
table RNQ47*(DTalcohol DTmarij DTbinge STalcohol STmarij STbinge)/chisq;
run;
proc freq data=work.LCA9;
table DTalcohol DTmarij DTbinge STalcohol STmarij STbinge;
run;
proc freq data=work.LCA9;
by RNQ47;
table DTalcohol DTmarij DTbinge STalcohol STmarij STbinge;
run;

data work.LCA10;set work.LCA9;
if polytobacco=1 and NQ8A5_2lvl=1 then PTalcohol=1;
else if polytobacco=0 or NQ8A5_2lvl=0 then PTalcohol=0;
 if polytobacco=. or NQ8A5_2lvl=. then PTalcohol=.;
run;
data work.LCA11;set work.LCA10;
if polytobacco=1 and NQ8A6_2lvl=1 then PTmarij=1;
else if polytobacco=0 or NQ8A6_2lvl=0 then PTmarij=0;
 if polytobacco=. or NQ8A6_2lvl=. then PTmarij=.;
run;
data work.LCA12;set work.LCA11;
if polytobacco=1 and BINGE_2lvl=1 then PTbinge=1;
else if polytobacco=0 or BINGE_2lvl=0 then PTbinge=0;
if polytobacco=. or BINGE_2lvl=. then PTbinge=.;
run;

proc freq data=work.LCA12;
table RNQ47*(PTalcohol PTmarij PTbinge)/chisq;
run;
proc freq data=work.LCA12;
table PTalcohol PTmarij PTbinge;
```

```
run;
proc freq data=work.LCA12;
by RNQ47;
table PTalcohol PTmarij PTbinge;
run;
proc freq data=work.LCA12;
by RNQ47;
table BINGE_2lvl*NQ8A5_2lvl;
run;
proc freq data=work.LCA12;
by RNQ47;
table BINGE_2lvl*NQ8A5_2lvl/chisq;
run;
proc freq data=work.LCA12;
table BINGE_2lvl*NQ8A5_2lvl;
run;


/*Multinomial Regression: All sample*/;
proc contents data=work.lca12 order=varnum;run;
proc freq data=work.lca12;
table PERMID;run;
proc logistic data = work.LCA12;
class CLASS_All (ref = "7")  / param = ref;
model CLASS_All = NQ46 RNQ47 PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_All (ref = "7") RACE (ref="1") / param = ref;
model CLASS_All = RACE RNQ47 PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_All (ref = "7") NQ51 (ref="1st year undergraduate") / param =
ref;
model CLASS_All = NQ51 RNQ47 PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_All (ref = "7") nq58_recode (ref="2") / param = ref;
model CLASS_All = nq58_recode RNQ47 PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_All (ref = "7") nq59 (ref="No") / param = ref;
model CLASS_All = nq59 RNQ47 PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_All (ref = "7") region (ref="West") / param = ref;
model CLASS_All = region RNQ47 PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_All (ref = "7") PUBPRIV (ref="Private") / param = ref;
model CLASS_All = PUBPRIV RNQ47 PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_All (ref = "7") locale_r (ref="2") / param = ref;
model CLASS_All = locale_r RNQ47 PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_All (ref = "7") nq63 (ref="A") / param = ref;
```

```
model CLASS_All = nq63 RNQ47 PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_All (ref = "7") size_r (ref="2") / param = ref;
model CLASS_All = size_r RNQ47 PERMID/ link = glogit;
run;

/*Multinomial Regression: Male sample*/;
proc logistic data = work.LCA12;
class CLASS_FEMA (ref = "6")  / param = ref;
model CLASS_FEMA = NQ46 PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_FEMA (ref = "6") RACE (ref="1") / param = ref;
model CLASS_FEMA = RACE PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_FEMA (ref = "6") NQ51 (ref="1st year undergraduate") / param =
ref;
model CLASS_FEMA = NQ51  PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_FEMA (ref = "6") nq58_recode (ref="2") / param = ref;
model CLASS_FEMA = nq58_recode  PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_FEMA (ref = "6") nq59 (ref="No") / param = ref;
model CLASS_FEMA = nq59  PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_FEMA (ref = "6") region (ref="West") / param = ref;
model CLASS_FEMA = region  PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_FEMA (ref = "6") PUBPRIV (ref="Private") / param = ref;
model CLASS_FEMA = PUBPRIV  PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_FEMA (ref = "6") locale_r (ref="2") / param = ref;
model CLASS_FEMA = locale_r  PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_FEMA (ref = "6") size_r (ref="2") / param = ref;
model CLASS_FEMA = size_r  PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_FEMA (ref = "6") nq63 (ref="A") / param = ref;
model CLASS_FEMA = nq63  PERMID/ link = glogit;
run;

/*Multinomial Regression: Male sample*/;
proc logistic data = work.LCA12;
class CLASS_MALE (ref = "6")  / param = ref;
model CLASS_MALE = NQ46 PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_MALE (ref = "6") RACE (ref="1") / param = ref;
```

```
model CLASS_MALE = RACE PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_MALE (ref = "6") NQ51 (ref="1st year undergraduate") / param =
ref;
model CLASS_MALE = NQ51  PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_MALE (ref = "6") nq58_recode (ref="2") / param = ref;
model CLASS_MALE = nq58_recode  PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_MALE (ref = "6") nq59 (ref="No") / param = ref;
model CLASS_MALE = nq59  PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_MALE (ref = "6") region (ref="West") / param = ref;
model CLASS_MALE = region  PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_MALE (ref = "6") PUBPRIV (ref="Private") / param = ref;
model CLASS_MALE = PUBPRIV  PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_MALE (ref = "6") locale_r (ref="2") / param = ref;
model CLASS_MALE = locale_r  PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_MALE (ref = "6") size_r (ref="2") / param = ref;
model CLASS_MALE = size_r  PERMID/ link = glogit;
run;
proc logistic data = work.LCA12;
class CLASS_MALE (ref = "6") nq63 (ref="A") / param = ref;
model CLASS_MALE = nq63  PERMID/ link = glogit;
run;
```

Appendix 4.1. SAS code for analysis of tracts Chapter 4a and 4b

```
*/analysis of tracts*/;
PROC IMPORT OUT= WORK.Tract
            DATAFILE= "C:\Users\micha\Dropbox\PhD\Dissertation\Paper
1\Data\\Final versions\To be analyzed\TractEcigs.xlsx"
            DBMS=XLSx;
RUN;
*/labeling race variables*/;

data work.tract1;
set work.tract;
rename HC03_VC49=Tract_Percent_White;
rename HC03_VC50=Tract_Percent_Black;
rename HC03_VC51=Tract_Percent_AIAN;
rename HC03_VC56=Tract_Percent_Asian;
rename HC03_VC64=Tract_Percent_NHPI;
rename HC03_VC69=Tract_Percent_OtherRace;
rename HC03_VC70=Tract_Percent_TwoMoreRaces;
rename HC01_VC49=Tract_N_White;
rename HC01_VC50=Tract_N_Black;
rename HC01_VC51=Tract_N_AIAN;
rename HC01_VC56=Tract_N_Asian;
rename HC01_VC64=Tract_N_NHPI;
rename HC01_VC69=Tract_N_OtherRace;
rename HC01_VC70=Tract_N_TwoMoreRaces;
rename HC01_VC23=Tract_MedianAge;
rename HC01_VC03a=Tract_TotalTractPop;
rename HC03_VC88=Tract_Percent_HispanicAnyRace;
rename HC01_VC88=Tract_n_HispanicAnyRace;
rename HC03_VC07=tract_perc_unemploy;
rename HC03_VC171=tract_perc_poverty;
rename HC01_EST_VC17=tract_perc_college;
run;
PROC CONTENTS DATA=WORK.Tract1 ORDER=VARNUM;RUN;
data work.tract2; set work.tract1;
if SESgroup=0 then delete;
else if SESgroup=. then delete;
if SESindicat=0 then delete;run;


*/Recoding of Race variables*/;
data work.tract5;set work.tract2;
Tract_Perc_OtherRace_recode=Tract_Percent_AIAN + Tract_Percent_Asian +
Tract_Percent_NHPI + Tract_Percent_OtherRace +
Tract_Percent_TwoMoreRaces;run;
data work.tract6; set work.tract5;
Tract_Percent_NonWhite=Tract_Percent_Black + Tract_Perc_OtherRace_recode;run;
```

```
proc freq data=work.tract6;
table Tract_Percent_White Tract_Percent_NonWhite;run;

*/coding for Tract diversity*/;
data work.tract7;set work.tract6;
if Tract_Percent_White >60 and Tract_Percent_NonWhite <=60 then
Tract_Diversity=1;
if Tract_Percent_White <=60 and Tract_Percent_NonWhite <=60 then
Tract_Diversity=2;
if Tract_Percent_White <=60 and Tract_Percent_NonWhite >60 then
Tract_Diversity=3;run;
proc sort data=work.tract7;
by CountyName;run;
proc freq data=work.tract7;
table Tract_Diversity;
by CountyName;run;
proc freq data=work.tract7;
table ecsum;
by CountyName;run;
proc freq data=work.tract7;
table CountyName;run;
proc tabulate data=work.tract7 ;
  class CountyName;
  var Ecsum;
  tables CountyName, Ecsum*(N sum);
run;

proc contents data=work.tract7 order=varnum;run;
*/ Determine if counts are normally distributed. They are not, poission or
negative binomial must be used/*;
PROC univariate DATA=WORK.Tract7;
var Ecsum;
histogram/MIDPOINTS=0,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16;
RUN;
PROC univariate DATA=WORK.Tract7;
var Shop_10km;
histogram;
RUN;

*/ Coding for number of retailers above and below the median and quartiles by
SES group*/;
data work.tract8; set work.tract7;
if Ecsum>2 then ECmedian=1;
else if Ecsum<=2 then ECmedian=0;
run;
proc univariate data=work.tract8;
var Tract_Percent_NonWhite;run;
PROC FREQ DATA=WORK.Tract8;
TABLE ECmedian;
by SESgroup;RUN;
data work.tract9; set work.tract8;
if Ecsum<1 then ECquar=1;
else if Ecsum>=1 and Ecsum<2 then ECquar=2;
else if Ecsum>=2 and Ecsum<5 then ECquar=3;
else if Ecsum>=5 then ECquar=4;
if Tract_Percent_NonWhite<17.55 then Tract_NonWhiteQuar =1 ;
else if 17.55<=Tract_Percent_NonWhite<32.65 then Tract_NonWhiteQuar =2;
```

```
else if 32.65<=Tract_Percent_NonWhite<58.40 then Tract_NonWhiteQuar =3;
else if Tract_Percent_NonWhite>=58.40 then Tract_NonWhiteQuar =4;
run;
proc tabulate data=work.tract9 ;
  class SESgroup;
  var ECmedian;
  tables SESgroup, ECmedian*(N sum);
run;
proc tabulate data=work.tract9 ;
  class SESgroup;
  var ECquar;
  tables SESgroup, ECquar*(N sum);
run;
proc sort data=work.tract9;
by county;run;
proc means data=work.tract9;
var ecsum;
by county;
run;

*/ There is not a significant difference between Census Tract Diversity in
relation to mean Ecigcount*/;
*/ There is a significant difference between Census Tract SESgroups in
relation to mean Ecigcount*/;
Proc Anova DATA=work.tract9;
class Tract_Diversity;
model Ecsum=Tract_Diversity;
means Tract_Diversity;run;quit;
Proc Anova DATA=work.tract9;
class SESgroup;
model Ecsum=SESgroup;
means SESgroup;run;quit;

*/average number of retailers examined by SESgroup and Diversity using ANOVA
analyses with Bonferroni pairwise comparisons*/;
Proc Anova DATA=work.tract9;
class SESgroup;
model Ecsum=SESgroup ;
means SESgroup/bon;run;quit;
Proc Anova DATA=work.tract9;
class Tract_Diversity;
model Ecsum=Tract_Diversity;
means Tract_Diversity/bon LINES;run;quit;
Proc Anova DATA=work.tract9;
class Tract_NonWhiteQuar;
model Ecsum=Tract_NonWhiteQuar;
means Tract_NonWhiteQuar/bon ;run;quit;

Proc Anova DATA=work.tract9;
class SESgroup;
model Shop_10km=SESgroup ;
means SESgroup/bon;run;quit;
Proc Anova DATA=work.tract9;
class Tract_Diversity;
model Shop_10km=Tract_Diversity;
means Tract_Diversity/bon LINES;run;quit;
```

```
Proc GLM data=work.tract9;
class SESgroup;
model Ecsum=SESgroup Population;
lsmeans SESgroup;run;quit;
Proc GLM data=work.tract9;
class Tract_Diversity;
model Ecsum=Tract_Diversity;
lsmeans Tract_Diversity;run;quit;
Proc GLM data=work.tract9;
class Tract_NonWhiteQuar;
model Ecsum=Tract_NonWhiteQuar;
lsmeans Tract_NonWhiteQuar;run;quit;

   proc reg data=work.tract9;
      model Shop_10km=tract_perc_unemploy;
   run;


*/Regression Analysis: Count*/;
proc contents data=work.tract9 order=varnum;run;
*/ the chi-sq indicated that the negative binomial model is a good fit*/;

*/Count/*;
*/ Assessing each SES variable*/;
proc genmod data=work.tract9;
model Ecsum=tract_perc_unemploy Tract_TotalTractPop/dist=nb pscale;
run;
proc genmod data=work.tract9;
model Ecsum=tract_perc_poverty Tract_TotalTractPop/dist=nb pscale;
run;
proc genmod data=work.tract9 ;
model Ecsum=med_value1 Tract_TotalTractPop/dist=nb pscale;
run;
proc genmod data=work.tract9;
model Ecsum=med_income Tract_TotalTractPop/dist=nb pscale;
run;
proc genmod data=work.tract9;
model Ecsum=LessHSgrad Tract_TotalTractPop/dist=nb pscale;
run;
proc genmod data=work.tract9;
model Ecsum=tract_perc_college Tract_TotalTractPop/dist=nb pscale;
run;

*/ Assessing each index variables*/;
proc genmod data=work.tract9;
class SESgroup (ref='4') ;
model ECquar=SESgroup /dist=nb pscale;
run;
proc genmod data=work.tract9;
class Tract_Diversity (ref='1') ;
model ECquar=Tract_Diversity /dist=nb pscale;
run;
proc genmod data=work.tract9;
class Tract_Diversity (ref='1') ;
model ECquar=Tract_Percent_NonWhite Tract_TotalTractPop/dist=nb pscale;
run;
```

```
*/adjustment of tract pop/*;
proc genmod data=work.tract9;
class SESgroup (ref='4') ;
model Ecsum=SESgroup Tract_TotalTractPop/dist=negbin pscale;
run;
proc genmod data=work.tract9;
class Tract_Diversity (ref='1') ;
model Ecsum=Tract_Diversity Tract_TotalTractPop/dist=nb pscale;
run;
proc genmod data=work.tract9;
class Tract_Diversity (ref='1') ;
model Ecsum=Tract_Percent_NonWhite Tract_TotalTractPop/dist=nb pscale;
run;

proc univariate data=work.tract9;
var shop_10km; histogram;run;
*/density/*;
*/ Assessing each SES variable*/;
proc genmod data=work.tract9;
model Shop_10km=tract_perc_unemploy Tract_TotalTractPop/dist=nb pscale;
run;
proc genmod data=work.tract9;
model Shop_10km=tract_perc_poverty Tract_TotalTractPop /dist=nb pscale;
run;
proc genmod data=work.tract9 ;
model Shop_10km=med_value1 Tract_TotalTractPop/dist=nb pscale;
run;
proc genmod data=work.tract9;
model Shop_10km=med_income Tract_TotalTractPop/dist=nb pscale;
run;
proc genmod data=work.tract9;
model Shop_10km=LessHSgrad Tract_TotalTractPop/dist=nb pscale;
run;
proc genmod data=work.tract9;
model Shop_10km=tract_perc_college Tract_TotalTractPop/dist=nb pscale;
run;

*/ Assessing each index variables*/;
proc genmod data=work.tract9;
class SESgroup (ref='4') ;
model Shop_10km=SESgroup /dist=nb pscale;
run;
proc genmod data=work.tract9;
class Tract_Diversity (ref='1') ;
model Shop_10km=Tract_Diversity /dist=nb pscale;
run;
proc genmod data=work.tract9;
class Tract_Diversity (ref='1') ;
model Shop_10km=Tract_Percent_NonWhite Tract_TotalTractPop/dist=nb pscale;
run;
*/adjustment of tract pop/*;
proc genmod data=work.tract9;
class SESgroup (ref='4') ;
model Shop_10km=SESgroup Tract_TotalTractPop/dist=negbin pscale;
run;
proc genmod data=work.tract9;
class Tract_Diversity (ref='1') ;
```

```
model Shop_10km=Tract_Diversity Tract_TotalTractPop/dist=nb pscale;
run;
proc genmod data=work.tract9;
class Tract_Diversity (ref='1') ;
model Shop_10km=Tract_Percent_NonWhite Tract_TotalTractPop/dist=nb pscale;
run;

proc sort data=work.tract9;
by PUtract;run;
proc means data=work.tract9;
var ECsum;
by PUtract;run;

proc sort data=work.tract9;
by AnySchooltract;run;
proc means data=work.tract9;
var Shop_10km;
by AnySchooltract;run;



proc anova data=work.tract9;
class PUtract;
model ECsum=PUtract;
run;

proc anova data=work.tract9;
class PRtract;
model ECsum=PRtract;
run;

proc anova data=work.tract9;
class AnySchooltract;
model ECsum=AnySchooltract;
run;

proc anova data=work.tract9;
class HEtract;
model ECsum=HEtract;
run;


proc anova data=work.tract9;
class PUtract;
model Shop_10km=PUtract;
run;

proc anova data=work.tract9;
class PRtract;
model Shop_10km=PRtract;
run;

proc anova data=work.tract9;
class AnySchooltract;
model Shop_10km=AnySchooltract;
run;
```

```
proc anova data=work.tract9;
class HEtract;
model Shop_10km=HEtract;
run;
```

Appendix 4.2 SAS code for analysis of schools for Chapter 4b

```
*/ANALYSIS OF PUBLIC SCHOOLS*/;
PROC IMPORT OUT= WORK.PUBLIC
            DATAFILE= "C:\Users\micha\Dropbox\PhD\Dissertation\Paper
1\Data\Final versions\To be analyzed\PublicTractBufferEcig.xls"
            DBMS=EXCEL REPLACE;
     RANGE="Public$";
     GETNAMES=YES;
     MIXED=NO;
     SCANTEXT=YES;
     USEDATE=YES;
     SCANTIME=YES;
RUN;
PROC CONTENTS DATA=WORK.PUBLIC ORDER=VARNUM;RUN;


*/CODING AND RECODING*/
*/Remove schools of other category and delete SESgroups that =0/*;
PROC FREQ DATA=WORK.PUBLIC1;
TABLE SESgroup SESindicat PUSchlLeve; RUN;
DATA WORK.PUBLIC1; SET WORK.PUBLIC;
if PUSchlLeve="4-Other" then delete;
if SESgroup=0 then delete;
else if SESgroup=. then delete;
if SESindicat=0 then delete;
else if SESindicat=. then delete;RUN;

*/schools and buffers/*;
PROC FREQ DATA=WORK.PUBLIC1;
TABLE Pusum800 Pusum1600;run;
DATA WORK.PUBLIC2; SET WORK.PUBLIC1;
IF Pusum800 >=1 THEN OUTLETYN800=1;
ELSE IF Pusum800<1 THEN OUTLETYN800=0;
IF Pusum1600 >=1 THEN OUTLETYN1=1;
ELSE IF Pusum1600<1 THEN OUTLETYN1=0;
IF Pusum3200 >=1 THEN OUTLETYN2=1;
ELSE IF Pusum3200<1 THEN OUTLETYN2=0;run;
PROC FREQ DATA=WORK.PUBLIC2;
TABLE OUTLETYN800 OUTLETYN1 OUTLETYN2 SESgroup TotalFLERP;RUN;

*/labeling race variables*/;
data work.public3;
set work.public2;
rename HC03_VC49=Tract_Percent_White;
rename HC03_VC50=Tract_Percent_Black;
rename HC03_VC51=Tract_Percent_AIAN;
rename HC03_VC56=Tract_Percent_Asian;
rename HC03_VC64=Tract_Percent_NHPI;
```

```
rename HC03_VC69=Tract_Percent_AnyOtherRace;
rename HC03_VC70=Tract_Percent_TwoMoreRaces;
rename HC01_VC49=Tract_N_White;
rename HC01_VC50=Tract_N_Black;
rename HC01_VC51=Tract_N_AIAN;
rename HC01_VC56=Tract_N_Asian;
rename HC01_VC64=Tract_N_NHPI;
rename HC01_VC69=Tract_N_AnyOtherRace;
rename HC01_VC70=Tract_N_TwoMoreRaces;
rename HC01_VC23=Tract_MedianAge;
rename HC01_VC03a=Tract_TotalTractPop;
rename HC03_VC88=Tract_Percent_HispanicAnyRace;
rename HC01_VC88=Tract_n_HispanicAnyRace;
run;
*/Recoding of Race variables*/;
data work.public4;set work.public3;
Tract_Perc_OtherRace_recode=Tract_Percent_AIAN + Tract_Percent_Asian +
Tract_Percent_NHPI + Tract_Percent_AnyOtherRace +
Tract_Percent_TwoMoreRaces;run;
data work.public5; set work.public4;
Tract_Percent_NonWhite=Tract_Percent_Black + Tract_Perc_OtherRace_recode;run;
proc freq data=work.public5;
table Tract_Percent_White Tract_Percent_NonWhite;run;

*/coding for Tract diversity*/;

data work.public6;set work.public5;
if Tract_Percent_White >60 and Tract_Percent_NonWhite <=60 then
Tract_Diversity=1;
if Tract_Percent_White <=60 and Tract_Percent_NonWhite <=60 then
Tract_Diversity=2;
if Tract_Percent_White <=60 and Tract_Percent_NonWhite >60 then
Tract_Diversity=3; run;
proc freq data=work.public6;
table Tract_Diversity;run;

*/ coding for School Diversity*/;
Proc contents data=work.public6 order=varnum;run;
data work.public7;set work.public6;
School_NonWhitePerc= PUBlackPer + PUOtherPer;run;
proc Freq data=work.public7;
table School_NonWhitePerc;run;
Data work.public8; set work.public7;
if PUWhitePer >.6 and School_NonWhitePerc <=.6 then School_diversity=1;
if PUWhitePer <=.6 and School_NonWhitePerc <=.6 then School_diversity=2;
if PUWhitePer <=.6 and School_NonWhitePerc >.6 then School_diversity=3;
if School_NonWhitePerc<.2905 then School_NonWhiteQuar =1 ;
else if 0.2905<=School_NonWhitePerc<0.4810 then School_NonWhiteQuar =2;
else if 0.4810<=School_NonWhitePerc<0.8185 then School_NonWhiteQuar =3;
else if School_NonWhitePerc>=0.8185 then School_NonWhiteQuar =4;
if PUWhitePer<0.1815 then School_WhiteQuar =1 ;
else if 0.1815<=PUWhitePer<.5190 then School_WhiteQuar =2;
else if 0.5190<=PUWhitePer<0.7090 then School_WhiteQuar =3;
else if PUWhitePer>=0.7090 then School_WhiteQuar =4;run;
proc Freq data=work.public8;
table School_WhiteQuar School_NonWhiteQuar;run;
proc univariate data=work.public8;
```

```
var School_NonWhitePerc PUWhitePer;run;

*/ coding for FLE % in schools*/;
proc univariate data=work.public8;
var TotalFLERP;run;
data work.public9;set work.public8;
if TotalFLERP <.19 then FLE_Quar=1;
else if .19<= TotalFLERP <.42 then FLE_Quar=2;
else if .42<= TotalFLERP<0.67 then FLE_Quar=3;
else if TotalFLERP>=0.67 then FLE_Quar=4;
run;
proc freq data=work.public9;
table FLE_Quar;run;

*/Frequencies*/;
Proc Freq data=work.public9;
table PUSchlLeve School_Diversity SESgroup OUTLETYN1 OUTLETYN800;run;
proc sort data=work.public9;
by PUCounty;run;
Proc Freq data=work.public9;
table PUSchlLeve;
by PUCounty; run;
PROC FREQ DATA=WORK.PUBLIC9;
table PUSchlLeve*(OUTLETYN1 OUTLETYN800 OUTLETYN2);run;
PROC FREQ DATA=WORK.PUBLIC9;
table PUSchlLeve*OUTLETYN1;run;
PROC FREQ DATA=WORK.PUBLIC9;
table School_NonWhiteQuar*OUTLETYN800;run;
proc univariate data=WORK.PUBLIC9;
var PUTotalStu;run;

proc univariate data=WORK.PUBLIC9;
var Pusum800;
histogram;run;

*/bivariate analysis*/;
Proc anova DATA=work.PUBLIC9;
class School_NonWhiteQuar;
model Pusum800=School_NonWhiteQuar  ;
means School_NonWhiteQuar;
run;quit;
Proc anova DATA=work.PUBLIC9;
class School_NonWhiteQuar;
model Pusum1600=School_NonWhiteQuar  ;
means School_NonWhiteQuar;
run;quit;
Proc anova DATA=work.PUBLIC9;
class School_NonWhiteQuar;
model Pusum3200=School_NonWhiteQuar  ;
means School_NonWhiteQuar;
run;quit;

proc anova data=WORK.PUBLIC9;
class FLE_Quar;
model Pusum800=FLE_Quar  ;
means FLE_Quar/ bon lines;
means FLE_Quar;
```

```
run;quit;
proc anova data=WORK.PUBLIC9;
class FLE_Quar;
model Pusum1600=FLE_Quar  ;
means FLE_Quar/ bon;
run;quit;
proc anova data=WORK.PUBLIC9;
class FLE_Quar;
model Pusum3200=FLE_Quar  ;
means FLE_Quar/ bon lines;
run;quit;

proc anova data=WORK.PUBLIC9;
class SESgroup;
model Pusum800=SESgroup  ;
means SESgroup/ bon;
run;quit;
proc anova data=WORK.PUBLIC9;
class SESgroup;
model Pusum1600=SESgroup  ;
means SESgroup/bon ;
run;quit;
proc anova data=WORK.PUBLIC9;
class SESgroup;
model Pusum3200=SESgroup  ;
means SESgroup/ bon lines;
run;quit;

proc anova data=WORK.PUBLIC9;
class School_Diversity;
model Pusum800=School_Diversity  ;
means School_Diversity/ bon;
run;quit;
proc anova data=WORK.PUBLIC9;
class School_Diversity;
model PUsum1600=School_Diversity  ;
means School_Diversity/ bon;
run;quit;
proc anova data=WORK.PUBLIC9;
class School_Diversity;
model Pusum3200=School_Diversity  ;
means School_Diversity/ bon lines;
run;quit;

proc anova data=WORK.PUBLIC9;
class PUSchlLeve;
model Pusum800=PUSchlLeve  ;
means PUSchlLevel/ bon lines;
run;quit;
proc anova data=WORK.PUBLIC9;
class PUSchlLeve;
model PUsum1600=PUSchlLeve  ;
means PUSchlLeve / bon lines;
run;quit;
proc anova data=WORK.PUBLIC9;
class PUSchlLeve;
model Pusum3200=PUSchlLeve  ;
```

```
means PUSchlLeve/ bon lines;
run;quit;

*/Modeling*/;
Proc contents data=work.public9 order=varnum;run;
proc univariate data=work.public9;
var PUsum800;
histogram;run;
proc univariate data=work.public9;
var PUsum1600;
histogram;run;
proc univariate data=work.public9;
var Shop_10km;
histogram;run;



proc genmod data=work.public9 ;
class SESgroup(ref="4")  ;
model PUsum800 =SESgroup  pop_density PUTotalStu/ link=log dist=negbin
pscale ;
run;
proc genmod data=work.public9;
class SESgroup(ref="4")  ;
model PUsum1600 =SESgroup  pop_density PUTotalStu/ dist=negbin   pscale;
run;
proc genmod data=work.public9;
class SESgroup(ref="4")  ;
model PUsum3200 =SESgroup  pop_density PUTotalStu/ dist=negbin   pscale;
run;

proc genmod data=work.public9;
class School_Diversity(ref="1") ;
model PUsum800 =School_Diversity pop_density PUTotalStu / dist=negbin
pscale;
run;
proc genmod data=work.public9;
class School_Diversity(ref="1") ;
model PUsum1600 =School_Diversity pop_density PUTotalStu / dist=negbin
pscale;
run;
proc genmod data=work.public9;
class School_Diversity(ref="1") ;
model PUsum3200 =School_Diversity pop_density PUTotalStu / dist=negbin
pscale;
run;

proc genmod data=work.public9;
model PUsum800  =TotalFLERP pop_density PUTotalStu /dist=negbin   pscale;
run;
proc genmod data=work.public9;
model PUsum1600  =TotalFLERP pop_density PUTotalStu /dist=negbin   pscale;
run;
proc genmod data=work.public9;
model PUsum3200  =TotalFLERP pop_density PUTotalStu /dist=negbin   pscale;
run;
```

```
proc genmod data=work.public9;
class FLE_Quar(ref="1") ;
model PUsum800 =FLE_Quar pop_density PUTotalStu /dist=negbin   pscale;
run;
proc genmod data=work.public9;
class  FLE_Quar(ref="1") ;
model PUsum1600  =FLE_Quar pop_density PUTotalStu /dist=negbin   pscale;
run;
proc genmod data=work.public9;
class  FLE_Quar(ref="1") ;
model PUsum3200  =FLE_Quar pop_density PUTotalStu /dist=negbin   pscale;
run;

proc genmod data=work.public9;
class PUSchlLeve(ref="1-Primary");
model PUsum800 =PUSchlLeve pop_density PUTotalStu /dist=negbin   pscale;
run;
proc genmod data=work.public9;
class  PUSchlLeve(ref="1-Primary");
model PUsum1600  =PUSchlLeve pop_density PUTotalStu /dist=negbin
pscale;run;
proc genmod data=work.public9;
class  PUSchlLeve(ref="1-Primary");
model PUsum3200  =PUSchlLeve pop_density PUTotalStu /dist=negbin
pscale;run;

proc logistic data=work.public9;
class SESgroup(ref="4")  ;
model OUTLETYN800 (event="1") =SESgroup   PUTotalStu;
run;
proc logistic  data=work.public9;
class SESgroup(ref="4")  ;
model OUTLETYN1 (event="1") =SESgroup    PUTotalStu;
run;
proc logistic  data=work.public9;
class SESgroup(ref="4")  ;
model OUTLETYN2 (event="1") =SESgroup   PUTotalStu;
run;

proc logistic data=work.public9;
class School_Diversity(ref="1") ;
model OUTLETYN800 (event="1") =School_Diversity   PUTotalStu;
run;
proc logistic data=work.public9;
class School_Diversity(ref="1") ;
model OUTLETYN1 (event="1") =School_Diversity   PUTotalStu;
run;
proc logistic data=work.public9;
class School_Diversity(ref="1") ;
model OUTLETYN2 (event="1") =School_Diversity   PUTotalStu;
run;

proc logistic data=work.public9;
model OUTLETYN800 (event="1") =TotalFLERP  PUTotalStu ;
units TotalFLERP=.1;
run;
proc logistic data=work.public9;
```

```
model OUTLETYN1 (event="1") =TotalFLERP  PUTotalStu ;
units TotalFLERP=.1;
run;
proc logistic data=work.public9;
model OUTLETYN2 (event="1") =TotalFLERP  PUTotalStu ;
units TotalFLERP=.1;
run;

proc logistic data=work.public9;
class  FLE_Quar(ref="1") ;
model OUTLETYN800 (event="1") =FLE_Quar  PUTotalStu ;
run;
proc logistic data=work.public9;
class  FLE_Quar(ref="1") ;
model OUTLETYN1 (event="1") =FLE_Quar  PUTotalStu ;
run;
proc logistic data=work.public9;
class  FLE_Quar(ref="1") ;
model OUTLETYN2 (event="1") =FLE_Quar  PUTotalStu ;
run;

proc logistic data=work.public9;
class  PUSchlLeve(ref="1-Primary") ;
model OUTLETYN800 (event="1") =PUSchlLeve  PUTotalStu ;
run;
proc logistic data=work.public9;
class  PUSchlLeve(ref="1-Primary") ;
model OUTLETYN1 (event="1") =PUSchlLeve  PUTotalStu ;
run;
proc logistic data=work.public9;
class  PUSchlLeve(ref="1-Primary") ;
model OUTLETYN2 (event="1") =PUSchlLeve  PUTotalStu ;
run;

*/ANALYSIS OF PRIVATE SCHOOLS*/;
PROC IMPORT OUT= WORK.PRIVATE
            DATAFILE= "C:\Users\sawdeymd\Dropbox\PhD\Dissertation\Paper 
1\Data\Original\Final versions\To be analyzed\PrivateTractBufferEcig.xls" 
            DBMS=EXCEL REPLACE;
     RANGE="Private$";
     GETNAMES=YES;
     MIXED=NO;
     SCANTEXT=YES;
     USEDATE=YES;
     SCANTIME=YES;
RUN;
PROC CONTENTS DATA=WORK.Private ORDER=VARNUM;RUN;

*/CODING AND RECODING*/
*/Remove schools of other category and delete SESgroups that =0/*;
PROC FREQ DATA=WORK.PRivate;
TABLE SESgroup SESindicat PRSchoolLevel; RUN;
DATA WORK.Private1; SET WORK.Private;
if PRSchoolLevel="4-Other" then delete;
if SESgroup=0 then delete;
else if SESgroup=. then delete;
if SESindicat=0 then delete;
```

```
else if SESindicat=. then delete;RUN;

*/schools and buffers/*;
PROC FREQ DATA=WORK.Private1;
TABLE Prsum800 Prsum1600;run;
DATA WORK.Private2; SET WORK.Private1;
IF PRsum800 >=1 THEN OUTLETYN800=1;
ELSE IF PRsum800<1 THEN OUTLETYN800=0;
IF PRsum1600 >=1 THEN OUTLETYN1=1;
ELSE IF PRsum1600<1 THEN OUTLETYN1=0;
IF PRsum3200 >=1 THEN OUTLETYN2=1;
ELSE IF PRsum3200<1 THEN OUTLETYN2=0;run;
PROC FREQ DATA=WORK.Private2;
TABLE OUTLETYN800 OUTLETYN1 OUTLETYN2 SESgroup;RUN;

PROC CONTENTS DATA=WORK.Private2 ORDER=VARNUM;RUN;
*/labeling race variables*/;
data work.private3;
set work.private2;
rename HC03_VC49=Tract_Percent_White;
rename HC03_VC50=Tract_Percent_Black;
rename HC03_VC51=Tract_Percent_AIAN;
rename HC03_VC56=Tract_Percent_Asian;
rename HC03_VC64=Tract_Percent_NHPI;
rename HC03_VC69=Tract_Percent_AnyOtherRace;
rename HC03_VC70=Tract_Percent_TwoMoreRaces;
rename HC01_VC49=Tract_N_White;
rename HC01_VC50=Tract_N_Black;
rename HC01_VC51=Tract_N_AIAN;
rename HC01_VC56=Tract_N_Asian;
rename HC01_VC64=Tract_N_NHPI;
rename HC01_VC69=Tract_N_AnyOtherRace;
rename HC01_VC70=Tract_N_TwoMoreRaces;
rename HC01_VC23=Tract_MedianAge;
rename HC01_VC03a=Tract_TotalTractPop;
rename HC03_VC88=Tract_Percent_HispanicAnyRace;
rename HC01_VC88=Tract_n_HispanicAnyRace;
run;
*/Recoding of Race variables*/;
data work.private4;set work.private3;
Tract_Perc_OtherRace_recode=Tract_Percent_AIAN + Tract_Percent_Asian +
Tract_Percent_NHPI + Tract_Percent_AnyOtherRace +
Tract_Percent_TwoMoreRaces;run;
data work.private5; set work.private4;
Tract_Percent_NonWhite=Tract_Percent_Black + Tract_Perc_OtherRace_recode;run;
proc freq data=work.private5;
table Tract_Percent_White Tract_Percent_NonWhite;run;

*/coding for "diversity" within tract"*/;
data work.private6;set work.private5;
if Tract_Percent_White >60 and Tract_Percent_NonWhite <=60 then
Tract_Diversity=1;
if Tract_Percent_White <=60 and Tract_Percent_NonWhite <=60 then
Tract_Diversity=2;
if Tract_Percent_White <=60 and Tract_Percent_NonWhite >60 then
Tract_Diversity=3;run;
proc freq data=work.private6;
```

```
table Tract_Diversity;run;

*/ coding for School Diversity, added nonwhite within excel*/;
Proc contents data=work.private6 order=varnum;run;

proc Freq data=work.private6;
table PRNonWhitePerc;run;
proc univariate data=work.private6;
var PRNonWhitePerc PRWhitePer;run;
Data work.private7; set work.private6;
if PRWhitePer >.6 and PRNonWhitePerc <=.6 then PRSchool_diversity=1;
if PRWhitePer <=.6 and PRNonWhitePerc <=.6 then PRSchool_diversity=2;
if PRWhitePer <=.6 and PRNonWhitePerc >.6 then PRSchool_diversity=3;
if PRNonWhitePerc<.14 then PRSchool_NonWhiteQuar =1 ;
else if 0.14<=PRNonWhitePerc<0.34 then PRSchool_NonWhiteQuar =2;
else if 0.34<=PRNonWhitePerc<0.63 then PRSchool_NonWhiteQuar =3;
else if PRNonWhitePerc>=0.63 then PRSchool_NonWhiteQuar =4;
if PRWhitePer<0.23 then PRSchool_WhiteQuar =1 ;
else if 0.23<=PRWhitePer<.65 then PRSchool_WhiteQuar =2;
else if 0.65<=PRWhitePer<0.86 then PRSchool_WhiteQuar =3;
else if PRWhitePer>=0.86 then PRSchool_WhiteQuar =4;
if PRSchoolLevel = '1-Primary' then PRSchoollevel1=1;
else if PRSchoolLevel='5-Combined' or PRSchoolLevel='6-Secondary'  then
PRSchoollevel1=2;
run;
proc Freq data=work.private7;
table PRSchool_Diversity PRSchoollevel1;run;

*/Frequencies*/;
Proc Freq data=work.private7;
table PRSchoolLevel PRSchool_Diversity SESgroup OUTLETYN1 OUTLETYN800;run;
proc sort data=work.private7;
by PRCountyNa;run;
Proc Freq data=work.private7;
table PRSchoolLevel;
by PRCountyNa; run;
PROC FREQ DATA=WORK.private7;
table PRSchoolLevel1*(OUTLETYN1 OUTLETYN800 OUTLETYN2);run;
PROC FREQ DATA=WORK.private7;
table PRSchoolLevel*OUTLETYN1;run;
PROC FREQ DATA=WORK.private7;
table PRSchoolLevel*OUTLETYN800;run;
proc univariate data=WORK.private7;
var PRTotalStu;run;

*/bivariate analysis*/;
Proc anova DATA=work.private7;
class PRSchool_NonWhiteQuar;
model PRsum800=PRSchool_NonWhiteQuar  ;
means PRSchool_NonWhiteQuar;
run;quit;
Proc anova DATA=work.private7;
class PRSchool_NonWhiteQuar;
model PRsum1600=PRSchool_NonWhiteQuar  ;
means PRSchool_NonWhiteQuar;
run;quit;
```

```
proc anova data=WORK.private7;
class SESgroup;
model PRsum800=SESgroup  ;
means SESgroup;
run;quit;
proc anova data=WORK.private7;
class SESgroup;
model PRsum1600=SESgroup  ;
means SESgroup;
run;quit;

proc anova data=WORK.private7;
class PRSchool_Diversity;
model PRsum800=PRSchool_Diversity  ;
means PRSchool_Diversity;
run;quit;
proc anova data=WORK.private7;
class PRSchool_Diversity;
model PRsum1600=PRSchool_Diversity  ;
means PRSchool_Diversity;
run;quit;

proc anova data=WORK.private7;
class PRSchoollevel1;
model PRsum800=PRSchoollevel1  ;
means PRSchoollevel1;
run;quit;
proc anova data=WORK.private7;
class PRSchoollevel1;
model PRsum1600=PRSchoollevel1  ;
means PRSchoollevel1;
run;quit;

*/Modeling*/;
PROC CONTENTS DATA=WORK.Private7 ORDER=VARNUM;RUN;
proc genmod data=work.private7 ;
class SESgroup(ref="4")  ;
model PRsum800 =SESgroup  pop_density PRTotalStu/ link=log dist=negbin
pscale ;
run;
proc genmod data=work.private7;
class SESgroup(ref="4")  ;
model PRsum1600 =SESgroup  pop_density PRTotalStu/ dist=negbin   pscale;
run;
proc genmod data=work.private7;
class PRSchool_Diversity(ref="1") ;
model PRsum800 =PRSchool_Diversity pop_density PRTotalStu / dist=negbin
pscale;
run;
proc genmod data=work.private7;
class PRSchool_Diversity(ref="1") ;
model PRsum1600 =PRSchool_Diversity pop_density PRTotalStu / dist=negbin
pscale;
run;
proc genmod data=work.private7;
model PRsum800 =PRNonWhitePerc pop_density PRTotalStu / dist=negbin   pscale;
run;
```

```
proc genmod data=work.private7;
model PRsum1600=PRNonWhitePerc pop_density PRTotalStu /dist=negbin   pscale;
run;
proc genmod data=work.private7;
class PRSchoollevel1(ref="1");
model PRsum800 =PRSchoollevel1 pop_density PRTotalStu /dist=negbin   pscale;
run;
proc genmod data=work.private7;
class  PRSchoollevel1(ref="1");
model PRsum1600  =PRSchoollevel1 pop_density PRTotalStu /dist=negbin
pscale;run;


proc logistic data=work.private7;
class SESgroup(ref="4")  ;
model OUTLETYN800 (event="1") =SESgroup  pop_density PRTotalStu;
run;
proc logistic  data=work.private7;
class SESgroup(ref="4")  ;
model OUTLETYN1 (event="1") =SESgroup pop_density PRTotalStu;
run;
proc logistic data=work.private7;
class PRSchool_Diversity(ref="1") ;
model OUTLETYN800 (event="1") =PRSchool_Diversity pop_density PRTotalStu;
run;
proc logistic data=work.private7;
class PRSchool_Diversity(ref="1") ;
model OUTLETYN1 (event="1") =PRSchool_Diversity pop_density PRTotalStu
/firth;
run;
proc logistic data=work.private7;
model OUTLETYN800 (event="1") =PRNonWhitePerc pop_density
PRTotalStu/clodds=wald ;
units PRNonWhitePerc=.1;
run;
proc logistic data=work.private7;
model OUTLETYN1 (event="1") =PRNonWhitePerc pop_density
PRTotalStu/clodds=wald ;
units PRNonWhitePerc=.1;
run;
proc logistic data=work.private7;
class  PRSchoollevel1(ref="1") ;
model OUTLETYN800 (event="1") =PRSchoollevel1 pop_density PRTotalStu ;
run;
proc logistic data=work.private7;
class  PRSchoollevel1(ref="1") ;
model OUTLETYN1 (event="1") =PRSchoollevel1 pop_density PRTotalStu ;
run;

*/ANALYSIS OF Universities/College*/;

PROC IMPORT OUT= WORK.HIGHERED
            DATAFILE= "C:\Users\sawdeymd\Dropbox\PhD\Dissertation\Paper
1\Data\Original\Final versions\To be
analyzed\UniversitiesTractBufferEcig.xls"
            DBMS=EXCEL REPLACE;
     RANGE="HE 1600$";
```

```
        GETNAMES=YES;
        MIXED=NO;
        SCANTEXT=YES;
        USEDATE=YES;
        SCANTIME=YES;
RUN;

PROC CONTENTS DATA=WORK.HIGHERED ORDER=VARNUM;RUN;
PROC FREQ DATA=WORK.HIGHERED;
TABLE HEsum800 HEsum1600;RUN;
DATA WORK.HIGHERED1; SET WORK.HIGHERED;
IF HEsum800 >=1 THEN OUTLETYN800=1;
ELSE IF HEsum800<1 THEN OUTLETYN800=0;
IF Buffer_HEsum1600 >=1 THEN OUTLETYN1=1;
ELSE IF HEsum1600<1 THEN OUTLETYN1=0;
if SESgroup=0 then delete;RUN;

*/labeling race variables*/;
data WORK.HIGHERED2;
set WORK.HIGHERED1;
rename HC03_VC49=Tract_Percent_White;
rename HC03_VC50=Tract_Percent_Black;
rename HC03_VC51=Tract_Percent_AIAN;
rename HC03_VC56=Tract_Percent_Asian;
rename HC03_VC64=Tract_Percent_NHPI;
rename HC03_VC69=Tract_Percent_AnyOtherRace;
rename HC03_VC70=Tract_Percent_TwoMoreRaces;
rename HC01_VC49=Tract_N_White;
rename HC01_VC50=Tract_N_Black;
rename HC01_VC51=Tract_N_AIAN;
rename HC01_VC56=Tract_N_Asian;
rename HC01_VC64=Tract_N_NHPI;
rename HC01_VC69=Tract_N_AnyOtherRace;
rename HC01_VC70=Tract_N_TwoMoreRaces;
rename HC01_VC23=Tract_MedianAge;
rename HC01_VC03a=Tract_TotalTractPop;
rename HC03_VC88=Tract_Percent_HispanicAnyRace;
rename HC01_VC88=Tract_n_HispanicAnyRace;
run;
*/Recoding of Race variables*/;
data WORK.HIGHERED3;set WORK.HIGHERED2;
Tract_Perc_OtherRace_recode=Tract_Percent_AIAN + Tract_Percent_Asian +
Tract_Percent_NHPI + Tract_Percent_AnyOtherRace +
Tract_Percent_TwoMoreRaces;run;
data WORK.HIGHERED4; set WORK.HIGHERED3;
Tract_Percent_NonWhite=Tract_Percent_Black + Tract_Perc_OtherRace_recode;run;
proc freq data=WORK.HIGHERED4;
table Tract_Percent_White Tract_Percent_NonWhite;run;

*/coding for "diversity" within tract"*/;
data WORK.HIGHERED5;set WORK.HIGHERED4;
if Tract_Percent_White >60 and Tract_Percent_NonWhite <=60 then
Tract_Diversity=1;
if Tract_Percent_White <=60 and Tract_Percent_NonWhite <=60 then
Tract_Diversity=2;
if Tract_Percent_White <=60 and Tract_Percent_NonWhite >60 then
Tract_Diversity=3;run;
```

```
proc sort data=WORK.HIGHERED5;
by HESchoolNa;run;
proc freq data=WORK.HIGHERED5;
table Tract_Diversity;
by HESchoolNa;run;

PROC CONTENTS DATA=WORK.HIGHERED5 ORDER=VARNUM;RUN;
proc sort data=WORK.HIGHERED5;
by CountyName;run;
Proc Freq data=WORK.HIGHERED5;
table CountyName;run;
PROC FREQ DATA=WORK.HIGHERED5;
TABLE OUTLETYN1 OUTLETYN800 SESgroup;RUN;
PROC FREQ DATA=WORK.HIGHERED5;
TABLE School_Nam*Buffer_EcigCount;RUN;
PROC FREQ DATA=WORK.HIGHERED5;
TABLE School_Nam*Buffer_EcigCount;RUN;
PROC FREQ DATA=WORK.HIGHERED5;
TABLE School_Nam*SESgroup;RUN;
PROC FREQ DATA=WORK.HIGHERED5;
TABLE School_Nam*Enrollment;RUN;

proc univariate DATA=WORK.HIGHERED1;
var Enrollment;RUN;
```

Vita

Michael David Sawdey was born December 31, 1986 in Tucson, Arizona and he is an American citizen. He graduated from Murrieta Valley High School, Murrieta, CA in 2005. He received his Bachelor of Science in Health Science from San Diego State University, San Diego, CA in 2010. He received a Master of Public Health from San Diego State University's Graduate School of Public Health in 2012.

Professional and Research Positions

2015-2017	Pre-doctoral Trainee, Virginia Commonwealth University, Center for the Study of Tobacco Products and Division of Epidemiology, Department of Family Medicine and Population Health
	Mentor: Elizabeth Prom Wormley, M.P.H, Ph.D.
2016	Teaching Assistant, Virginia Commonwealth University, Division of Epidemiology, Department of Family Medicine and Population Health
	Mentor: Steven Cohen, Dr.PH.
2013-2015	Graduate Assistant, Virginia Commonwealth University, Division of Epidemiology, Department of Family Medicine and Population Health
	Mentor: Resa Jones, M.P.H, Ph.D.
2009-2012	Undergraduate and Graduate Assistant, San Diego State University, Graduate School of Public Health
	Mentor: Thomas Novotny, M.D., M.P.H.
2010-2012	Graduate Assistant, California Department of Public Health, Vaccines for Children Program

Publications

Sawdey MD, Hancock LC., Cohen, SA, Breland, AB, Eissenberg, TE. Prom-Wormley, EC. *Trends and Predictors of Tobacco and Polytobacco Use in US College Students between 2008-2014* (*in-preparation*)

Sawdey MD, Hancock LC., Cohen, SA, Breland, AB, Eissenberg, TE. Prom-Wormley, EC. *Latent Class Analysis of Male and Female College Students us of Tobacco, Alcohol, and Marijuana* (*in-preparation*)

Sawdey MD, Hancock LC., Cohen, SA, Breland, AB, Eissenberg, TE. Prom-Wormley, EC. *Using E-cigarette Brand Websites for Assessing Tobacco Availability Around Schools in Richmond, Virginia* (*submitted*)

Sawdey MD, Jones RM., & Prom-Wormley, EC. *Gender Differences in Poly-Substance Use and Perception of Peer Substance Use among College Students* (*in-preparation*)

Sawdey MD, Hancock LC, Messner M, & Prom-Wormley EC. *Assessing the Association between E-Cigarette Use and Exposure to Social Media in College Students: A Cross-Sectional Study.* (*submitted*)

Sawdey MD, Lindsay RP, & Novotny TE. (2011). *Smoke-free college campuses: no ifs, ands or toxic butts*. Tobacco Control, 20 Suppl 1, i21-i24. (*published)*

Presentations

Virginia Commonwealth University, Center for the Study of Tobacco Products. "E-cigarette Availability Around K-12 Public Schools and in Neighborhoods in Richmond, VA". (March 2017)

American Public Health Association National Meeting 2016. "Tobacco Availability by Socioeconomic Status Around Schools in Richmond, Virginia". (October 2016)

Virginia Commonwealth University, Division of Epidemiology Weekly Seminar. "Tobacco Availability by Socioeconomic Status Around Schools in Richmond, Virginia". (October 2016)

Virginia Commonwealth University, Center for the Study of Tobacco Products. "E-cigarette Availability in Richmond: A study in progress". (March 2016)

Virginia Commonwealth University, Division of Epidemiology Weekly Seminar. "E-cigarettes: The Current Debate and Availability in the Richmond, VA Metropolitan Statistical Area". (March 2016)

Virginia Commonwealth University, Division of Epidemiology Weekly Seminar. "The Relationship between College Students' Perception of Substance use among Peers and Self-Reported Substance use". (March 2015)

Virginia Healthy Youth Foundation Annual Meeting 2015. "Data blitz: Substance use among VCU College Students". (January 2015)

American Public Health Association National Meeting 2014. “The Relationship between College Students’ Perception of Substance use among Peers and Self-Reported Substance use”. (November (2014)

Virginia Healthy Youth Foundation Annual Meeting 2014. “Data blitz: Number of Perceived Substances vs. Average Number of Substances used among College Students”. (January 2014)

San Diego Epidemiology Research Exchange 2012. “College students’ perception of smoking among peers and self-reported smoking”. (May 2012)

California Youth Advisory Network, Youth Quest Annual Meeting 2012 Sacramento, CA. “The Environmental Impact of Cigarette Butts”. (March 2012)

Santee, CA community meeting. “The Environmental Impact of Cigarette Butts”. (February 2012)

San Diego State University Student Research Symposium. “Smoke-free College Campuses: No Ifs, Ands, or Toxic Butts”. (October 2011)