UNIVERSITY OF CALIFORNIA, SAN DIEGO

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Using Cluster Analysis to Investigate the Association between Smoke-free Homes, Light Smoking, and Cessation Behaviors

A dissertation submitted in partial satisfaction of the
requirements for the degree Doctor of Philosophy

in

Public Health (Health Behavior)

by

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Chair

University of California, San Diego

San Diego State University

2017

DEDICATION

For MLT and our GBs.

Thank you for your love, support, patience, and teaching me that everyone's a bit of a fixer upper, but when push comes to shove, the only fixer upper fixer that can fix a fixer upper is true, true, true, true love .....

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LIST OF ACRONYMS

30D-A	30 days or longer abstinence
AHRQ	Agency for Healthcare Research and Quality
ANRF	American Nonsmokers' Rights Foundation
BIC	Bayesian Information Criterion
CAPI	Computer-assisted personal interview
CATI	Computer-assisted telephone interview
CPD	Cigarettes per day
CPS	Current Population Survey
HH	Household
IARC	International Agency for Research on Cancer
NHB	Non-Hispanic Black
NHW	Non-Hispanic White
PHS	Public Health Service
QA	Quit attempt
RDM	Ratio of distance measure
SE	Self-efficacy
SFH	Smoke-free home
SQ	Successful quit
SR	Systematic review
TUS	Tobacco-Use Supplement
USPSTF	United States Preventive Services Task Force
VIF	Variance inflation factor
WHO	World Health Organization

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2. Ganiats TG, **Kempster JA**. (2014) Rationing on the fly: the opportunity cost of clinical guidelines. *J Am Board Fam Med,* 27:439–41.

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Commissioned Reports

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2. California Health Benefits Review Program (CHBRP). (2011). *Analysis of Assembly Bill 185: Maternity Services.* Report to California State Legislature. Oakland, CA: CHBRP. 11-06.

3. NICE Cost impact project. Supporting investment in public health: Review of methods for assessing cost effectiveness, cost impact and return on investment. Proof of concept report. (March 2011). [&]

4. California Health Benefits Review Program (CHBRP) (2011). *Analysis of Assembly Bill 72: Health Care Coverage: Acupuncture.* Report to California State Legislature. Oakland, CA: CHBRP. 11-03.[&]

5. Increasing the uptake of HIV testing to reduce undiagnosed infection and prevent transmission among men who have sex with men. Part of NICE public health guidance 34. March 2011.[&]

6. National Institute for Health and Clinical Excellence. Economic analysis to inform the development of NICE public health intervention guidance on information, sun protection resources and physical changes to the environment to prevent skin cancer (phase 2). Part of NICE public health guidance 32. January 2011.[&]

7. Barrow Cadbury Trust. Economic analysis of interventions for young adult offenders. 2009.[&]

8. A Picture of Health for Bexley, Bromley, Greenwich & Lewisham. Health Inequalities Impact Assessment and Equality Impact Assessment. 2008.[&]

[&] Published when working for Matrix Knowledge Group Consultancy, London, UK

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ABSTRACT OF DISSERTATION

Using Cluster Analysis to Investigate the Association between Smoke-free Homes, Light Smoking, and Cessation Behaviors

by

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Doctor of Philosophy in Public Health (Health Behavior)

University of California, San Diego, 2017

San Diego State University, 2017

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Background: Smoking cessation rates were stable in the 20 years to 2011. This is surprising given the concurrent desirable trends in many cessation-related behaviors, including smoke-free homes (SFH) and cigarettes per day (CPD). This could be the result of patterns of characteristics and behaviors having different associations with cessation than the individual associations may suggest. Understanding such associations could give new insights into the smoking population and help to improve policy and interventions.

Objectives: To identify homogeneous smoker sub-groups and compare their one-year odds of quitting behaviors and cessation-related behaviors, CPD and SFH. To identify trends in these behaviors in the sub-groups.

Participants: Adult smokers (n=2569) who completed the longitudinal 2010-11, Tobacco Use Supplement of Current Population Survey; 1447 had no SFH and 1799 consumed 10+ CPD at baseline.

Methods: Logistic regression identified variables associated with quitting, which were used in cluster analysis to identify smoker sub-groups. Sub-group predictive validity was tested for four outcomes: quit attempt (QA), 30-day abstinence (30D-A), SFH implementation, and reduced CPD.

Results: Four cluster subgroups were characterized by their combination of smoking intensity, nicotine dependence, and SFH status: *high dependence home smokers* (n=700, ref.), *high dependence smokers with a SFH* (n=458), *low intensity smokers* (n=446), and *low dependence moderate-heavy smokers* (n=488). One non-homogenous cluster grouped racial/ethnic *minority smokers* (n=477). QAs were higher than in the reference group than all other sub-groups. Given a QA, only *low intensity smokers* (OR_{adj}=2.18, p=0.01) and *low dependence moderate-heavy smokers* (OR_{adj}=2.15, p=0.04), both containing predominantly low dependence smokers, were more likely to report 30D-A.

High dependence smokers with a SFH were no more likely to reduce to <10 CPD than *high dependence home smokers* (19.7% vs 16.3%; OR_{adj}=0.68, p=0.07). *Low dependence moderate-heavy smokers* were equally likely to introduce a SFH as *high dependence home smokers* (OR_{adj}=1.21, p=0.09).

Conclusions: Contrary to findings in the literature, having a smoke-free home is not associated with a reduction to light smoking among heavier smokers. Both smoke-free homes and a reduction in consumption are diffusing fairly rapidly in all sub-groups of the US smoking population.

CHAPTER ONE

Background and Overview

Smoking prevalence has steadily declined since the Surgeon General's report of 1964 outlined the adverse effects of smoking tobacco on health (U.S. Department of Health Education and Welfare 1964), declining from 42.5% in 1965 (Garrett et al. 2011) to 19.0% in 2011 (Agaku, King, and Dube 2012). Since the end of the 1990s, a key driver of the decline in smoking prevalence has been smoking initiation in young people, who take up cigarette smoking at much lower rates than previous cohorts (Agaku, King, and Dube 2014). Although tobacco control efforts are associated with a significant reduction in smoking initiation, the cessation rate was stable between the early 1990s and 2010 (Zhu et al. 2012) following a period of incline between 1965 and 1987 (Fiore et al. 1989; Pierce et al. 1989). Despite little evidence of a change in cessation rates over the 20 years from the early 1990s to 2010, smokers' patterns of behavior have changed.

One of the most significant changes in smokers' behavior has been the reduction in the consumption of cigarettes, which declined throughout the 1980s (U.S. Department of Health and Human Services 1989) to an average daily consumption of 20 in 1991 (Centers for Disease Control and Prevention's (CDC) National Center for Health Statistics (NCHS) 1993), declining further in the subsequent 20 years to 15.1 in 2011 (Agaku et al. 2012). Over this time, more smokers have reported smoking less than 10 cigarettes per day (CPD) (Agaku et al. 2012). Another significant change in smoking-related behavior is the voluntary implementation of smoke-free homes among smokers. The national prevalence of having a smoke-free home amongst households with at least one adult smoker increased from 9.6% during 1992–1993 to 46.1% during 2010–2011 (King, Patel, and Babb 2014). The broader population also made changes during this period, with smoke-free home prevalence amongst households with no adult smokers increasing from 56.7% during 1992–1993 to 91.4% during 2010–2011 (King et al. 2014). Voluntary implementation of a smoke-free home has been

associated with living in a county or state with smoke-free laws (Cheng, Glantz, and Lightwood 2011), suggesting the increase in the prevalence of smoke-free homes could result from the same social norms that drive ordinances and laws to protect nonsmokers in indoor workplaces (Dai and Hao 2016). CDC estimated that in 2000 only 2.72% of the US population was protected by comprehensive smoke-free laws (statutes that prohibit smoking in indoor areas of worksites, restaurants, and bars), by 2010 this was 47.8% (Tynan et al. 2011). Attitudes to smoking and the public image of smoking have also changed over the last 50 years (Cummings and Proctor 2014). The social acceptance of smoking declined significantly between 2001 and 2011 (Cummings and Proctor 2014; Gilpin, Lee, and Pierce 2004), also concurrent with the introduction of smoke-free laws, higher taxes on cigarettes, and investment in anti-tobacco mass media campaigns (Cummings and Proctor 2014).

1.1 Proposed Theory of Stable Cessation Rate

With so many anti-tobacco changes in smoking-related behavior, the personal and policy tobacco environment, and personal cognitions and attitudes about smoking, behavior theory would predict an increase in the smoking cessation rate. According to Social Cognitive Theory, which is an interpersonal-level theory based on the model of triadic reciprocal causation, internal personal factors, behavioral patterns, and environmental events act as interactive determinants of one another (Bandura 1999). Applying this framework to the smoking population, the changes in smoking behavior patterns, cognitions and attitudes, and multiple levels of the environment, would interact to produce changes in cessation behaviors, such as attempting to quit and abstaining from smoking (Bandura 1999).

As smoking cessation occurs at the single person level not the population level, the relationships between the personal factors (cognitive, affective, and biological events), behaviors, and environmental events that accompany a successful quit attempt are likely to be

heterogeneous across the smoking population. While environmental factors, such as taxes and smoke-free laws, are imposed on a smoker, the cognitive, affective, and behavioral response to these changes depend on the individual. Over time, smokers who have responded to changes in a way that has facilitated cessation are likely to have quit, leaving a heterogeneous population of those continuing to smoke (Agaku et al. 2012) and joined by new smokers, who are known to exhibit different patterns of smoking behavior (Messer et al. 2008). The remaining (and new) smokers may exhibit different interdependencies between personal, behavioral, and environmental factors compared to former smokers. These differences could account for changes in some behaviors, such as smoking intensity, which is often associated with a failed quit attempt (QA) (Knoke, Anderson, and Burns 2006; Yong et al. 2008), but not in cessation. They could also be more heterogeneous with respect to smoking-related and cessation-related variables than former smokers. Examining the associations of the smoking-related behaviors associated with quitting could give further insights into the mechanisms responsible for an unchanged cessation rate and identify the constructs that act as barriers to cessation in some smokers.

1.2 Evidence for Proposed Theory of Stable Cessation Rate

Smoking-related behaviors, personal factors, and environmental factors have changed at the population-level change over the last 50 years (Center for Disease Control 2014). While many of the same variables continue to predict smoking cessation (Vangeli et al. 2011), the distribution of smokers within these variables may likely have changed. For example, smoking intensity has long been associated with cessation. But, the average daily consumption has changed significantly since the 1980s (Center for Disease Control 2014), leading to a reduction in the mean and mode smoking intensity. This raises questions about the consistency

of the relationships between smoking intensity and cessation behaviors, cognitions, and environment.

There are also factors that have been identified as predictors of cessation in the past, but are now so prevalent that there is little variation across the smoking population, for example, smoke-free office workplaces. The stable smoking cessation rate coupled with population-level changes in many behavioral and environmental factors associated with cessation, implies that interventions could be more effective in studies than the general smoking population (Zhu et al. 2012). Efforts to improve effectiveness in the population have included identifying segments of the population to target with communication and interventions (Hill et al. 2014; Nierkens et al. 2013; Zhu et al. 2012).

1.3 Identifying Subgroups for Targeting Interventions

Identifying subgroups in a population is beneficial when the population of interest is heterogeneous, both in terms of their characteristics and with respect to the outcome of interest (Everitt et al. 2011). This can include identifying and prioritizing some subgroups or segmenting the whole population (Vuik, Mayer, and Darzi 2016). Targeted smoking cessation interventions have commonly identified sub-populations to target by identifying *a priori* groups that have a higher prevalence of smoking than the population as a whole (Fagan et al. 2004). Demographic variables have also been used to segment the smoking population to identify targets for intervention, resulting in the development of programs that target a specific group. For example, low-income smokers (Hahn et al. 2004; Loughlin et al. 1999; Solomon et al. 2000, 2005), minority smokers race-ethnicity (R/E) smokers (Branstetter, Mercincavage, and Muscat 2015; Hopkins et al. 2001; Lawrence et al. 2003), smokers with low education levels (Siahpush et al. 2010), and sexual minorities (Lee et al. 2014). Smokers with comorbid health problems often have higher smoking prevalence rates than the general population. For

example, smoking is significantly more prevalent in people with mental health problems (Lasser et al. 2000; Lawrence, Mitrou, and Zubrick 2009) and those who are disabled (CDC 2016), have also been the targets of numerous smoking cessation efforts.

1.4 Problems with Using *A Priori* Subgroups for Intervention Targeting

While these more traditional methods of using subgroups to identify targets for intervention are important in addressing disparities (Fagan et al. 2004; Gornick, Eggers, and Riley 2001), they are associated with a number key challenges with respect to improving the overall smoking cessation rate. Firstly, a large proportion of smokers are not targeted because a large number of smokers do not belong to any high prevalence demographic and comorbid groups (Kent et al. 2010). This is especially true when considering the absolute number of people that are not targeted by using demographic and comorbid subgroups. For example, while the prevalence of smoking in people below the poverty line in 2012 was 27.9% compared to 17.0% (Agaku et al. 2014) of those at or above the poverty line, the proportion of people in poverty in 2012 was 15.3% (Bishaw 2013). This means, in absolute terms, for every three people below the poverty line that smokes, there are 10 people at or above the poverty line who also smoke. While it is incredibly important to continue to address health disparities, if smoking cessation rates are to improve rapidly, research in the smokers that do not meet any of the high-risk criteria also needs to be undertaken to ensure their cessation needs are understood and addressed. It is possible that some of the people not previously targeted share traits with those who are in previously targeted demographic and comorbid groups and may benefit from similar interventions. It is also possible smokers who are not in high prevalence subgroups have different reasons for not quitting smoking and require interventions tailored to their specific needs.

The second problem with demographic and comorbid subgroups is they are usually identified by evaluating the prevalence of smoking in a group rather than the risk for continuing to smoke. When smoking cessation is the outcome of interest, identifying groups that are least likely to quit is more important than prevalence (Vuik et al. 2016). There could be groups of individuals that are not in high prevalence subgroups, but are in low cessation rate subgroups who could benefit from tailored interventions.

Lastly, there are many different groups with a higher than average smoking prevalence. Approaching each of these groups separately leads to the development of many interventions in silos. Finding commonalities between the groups may lead to fewer and consequently more efficient interventions. For example, Siahpush and colleagues (Siahpush et al. 2010) reported that lower levels of education are associated with high nicotine dependence, low self-efficacy, and low intention to quit. This is consistent with bidirectional interdependencies between personal factors, such as education level, self-efficacy, and intention to quit, and behaviors that impact nicotine dependence (Bandura 1999). It is likely that other traditional *a priori* subgroups are also associated with high nicotine dependence, low self-efficacy, and low intention to quit in the same way as education level, which may indicate that both groups could benefit from interventions targeting the same behaviors.

Given that everyone in the smoking population is at risk for the adverse effects of continuing to smoke, identifying combinations of personal, behavioral, and personal environment variables associated with quitting behavior across the entire smoking population could be a beneficial approach to improve understanding of the smoking population as a whole and inform more effective and efficient targeted interventions.

1.5 Whole Population Segmentation for Identifying Target Groups

Segmenting a population into subgroups assigns each member of the population of interest to a group with people who are similar with respect to a defined set of traits (Everitt et al. 2011). People assigned to other groups are different with respect to the same set of traits. The purpose of reducing the individual traits into combinations is efficiency. In an ideal world every smoker would be given a smoking cessation program tailored specifically to his or her individual needs, however, this is clearly not feasible. Instead, assuming that the traits used to derive the subgroups are key drivers of the outcome, the differences between the subgroups could reflect different cessation needs and cover all smokers. This approach could also ensure that some groups are not systematically under-targeted (Vuik et al. 2016).

1.6 Cluster Analysis for Whole Population Segmentation

Cluster analysis is a statistical technique that classifies all individuals from a population into groups based on the co-occurrence of specified behaviors and characteristics (Everitt et al. 2011). In the past it has been commonly used to analyze the patterns of different health behaviors, such as smoking, diet, and physical activity (Patterson, Haines, and Popkin 1992; Vries et al. 2008). More recently, it has been used to look at a variety of behaviors specific to a single health behavior, for example alcohol consumption and obesity (Bräker and Soellner 2016; Green et al. 2015). In smoking, cluster analysis has focused on identifying heterogeneity based on quitting cognitions (Dijkstra and De Vries 2000; Smit, Hoving, and de Vries 2010) and stages of change level (Norman et al. 2000; Velicer et al. 1995). However, restricting the variables included in the clustering process to quitting cognitions ignores the interdependencies between the other types of personal variables, biological and affective, and the behavioral and environmental influences on quitting behaviors (Bandura 1999). In addition, measures of quitting cognitions can be unreliable depending on when they are

conducted (Gwaltney et al. 2009). They can also be subject to spontaneous change based on mood, personal circumstances, and social situation (Armitage and Arden 2008; Armitage and Conner 2001; Hughes et al. 2005), which could add unmeasured variation to the cluster models and impact the validity of the cluster solution.

Identifying personal, behavioral, and environmental characteristics associated with attempting to quit smoking and being successful and using the most appropriate subset of these variables to cluster the 2010/11 smoking population assigned every smoker in the study to a group with similar smokers with respect to salient cessation-related variables identified from all categories of the social cognitive theory.

1.7 Overview of the Project

Following a qualitative evidence review to comprehensively identify factors associated with quit attempt and cessation, both unadjusted and adjusted analyses were undertaken to ascertain which of the variables identified in the evidence review are the most appropriate candidate variables for segmenting the smoking population using cluster analysis. Identifying candidate variables for cluster analysis in an evidenced-based empirical manner should ensure that any underlying structures identified by the cluster analysis are relevant to smoking cessation outcomes.

After selection of the candidate clustering variables, testing was used to determine whether a valid cluster model can segment the whole smoking population into meaningful groups with respect to variables significantly associated with attempting to quit smoking (QA) and 30 day or longer abstinence at one year follow-up (30D-A). Tests of association between the subgroups with other smoking-related variables were undertaken to evaluate face validity of the cluster groups.

Following identification and characterization of the cluster groups, their predictive validity with respect to smoking cessation outcomes of interest: QA and 30D-A were tested. Characteristics of cluster groups that exhibited different odds of QA and 30D-A were compared to identify potentially important differences in their profiles. Finally, the utility of the clusters groups in identifying different trajectories of change in the two smoking-related behaviors changing across the whole smoking population: living in a smoke-free home (SFH) (King et al. 2016) and reducing consumption to less than 10 CPD (Pierce et al. 2011) were assessed.

By identifying smoker subgroups and evaluating whether they have differential odds of changing their smoking-related behaviors, making a QA, and achieving 30D-A, it may be possible to identify new subgroups, provide useful comparison groups for future research into the smoking population, and be helpful in identifying meaningful subgroups with potentially different cessation support needs.

1.7.1 Research Question:

Does segmenting the smoking population by combined personal, environmental, and personal environment characteristics provide new insights into the subgroups of smokers more likely to engage in quitting or harm-reducing behaviors?

1.7.2 Research Objectives:

1. To identify whether the 2010/11 smoking population can be clustered into subgroups based on the factors independently associated with QA and 30D-A (outcome variables).
2. To verify that smoker subgroups identified by this cluster analysis vary significantly in the odds of QAs and cessation.
3. To evaluate whether the smoker subgroups vary significantly in the odds of changing smoking-related behaviors which are changing at the population level, namely SFH implementation in those without a SFH at baseline and CPD reduction to light smoking in those who smoke >10 CPD at baseline.

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CHAPTER TWO

Identifying Salient Variables For Use in Cluster Analysis Evidence Review

2.1 Introduction and Evidence Review Framework

Smokers are a heterogeneous group with respect to demographics, lifestyle, attitudes and values, and geography and people across all demographic groups in all parts of the US continue to smoke (Agaku, King, and Dube 2014). One commonality within the smoking population is the desire to quit smoking. In 2010/11, 69% reported a desire to quit and 43% said they made an attempt, a rate that hasn't changed over a number of years (Centers for Disease Control and Prevention's (CDC) 2011). For many smokers in the US, and after many unsuccessful quit attempts, successful cessation remains elusive (Borland et al. 2011; Partos et al. 2013).

The idea that a "one size fits all" approach to the promotion and facilitation of smoking cessation may result in the availability of a narrow range of messages and interventions that are not applicable to everyone that smokes (Weinstein 1987). However, in the absence of a physiological "silver bullet," segmenting the smoking population according to their different traits may help to improve the tailoring of messages and behavior-based interventions and ensure that smokers get the most effective information and help.

Cluster analysis is used to segment a population and aims to assign individuals to groups that are homogeneous with respect to a set of variables salient to the research area. The technique simultaneously maximizes within-group similarity while maximizing between-group differences, resulting in groups of very similar individuals that are very different to people in the other groups. When conducting a cluster analysis using secondary data, a key task is identifying which of the available variables are salient to the problem or research area. As cluster analysis is a data-driven method, the variables included in the final cluster solution are dictated by the data, but the candidate variables, from which the models are built, are at the

discretion of the analyst. This chapter describes the evidence review conducted to identify the salient variables for inclusion in a cluster analysis of smokers.

Evidence of the variables associated with quit attempts (QA) and successful quit (SQ) can be derived two places: academic literature and so-called “grey literature” (National Institute for Health and Care Excellence 2014). Figure 2.1.1 is a framework for the flow of evidence from research to practice, which informed the evidence review of factors associated with QA and SQ. For the purposes of this study, the literature search strategy was applied to the following sources: synthesized and pooled evidence from systematic reviews and meta-analyses, primary evidence from research and survey findings carried out since the last systematic review and/or meta-analysis, guidance and guidelines from professional and government entities, and evidence from state tobacco control plans.

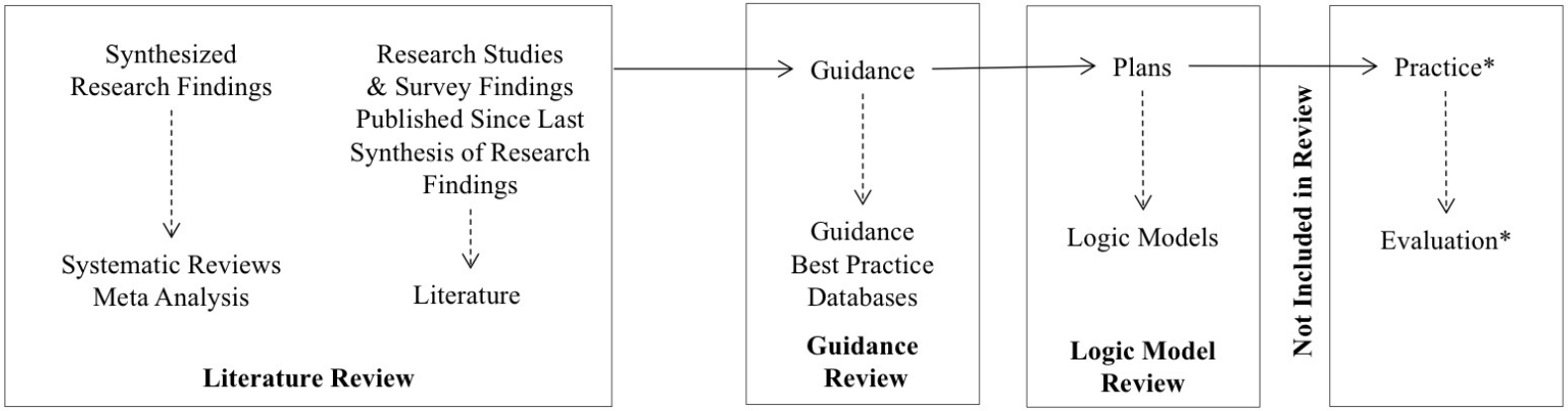

Figure 2.1.1 Framework of Evidence Review

* Excluded from review due to inconsistent public availability of information

2.2 Literature Review

2.2.1 Review of Synthesized Research Findings

Systematically reviewing the academic literature is an appropriate starting point for all evidenced-based projects (Bero and Jadad 1997). Understanding what is currently known about a topic, including conflicting results and different definitions of measures, allows researchers to devise an analytic plan using the most relevant and contemporary evidence and to anticipate any controversial analytic decisions.

The first part of the literature review component of the evidence review process involved searching for systematic reviews and meta-analyses identifying the variables associated with quit attempt and success in the literature, in order to identify whether an appropriate systematic review was available for update (Figure 2.2.1). The following **search terms** were used to query the databases: smoking AND (cessation OR quit OR stop OR abstinence) AND (predict* OR associat*) AND (population OR national OR international) AND ("systematic review" OR meta-analy* OR metaanaly* OR "evidence synthesis"). The databases searched included Pubmed, ISI web of knowledge (with Medline 1950- 2010 and web of science with conference proceedings 1945 - 2010), and PsychINFO (1806 – 2010).

The following study **inclusion criteria** were used to review the results: general population sample (i.e. not recruited for comorbid conditions or only including specific demographic groups), adult participants (≥ 18 years of age), specifically examining predictors of quit attempts and/or specifically examining success in those who made a quit attempt (inclusive definitions of attempt and success were permissible), does not involve a clinical intervention, and written in English. The **exclusion criteria** were: articles examining the same predictor variables from the same study and duplicating waves (i.e., a study reporting same partial/complete sample as another).

2.2.1.2 Result of the review of synthesized research findings

Of 133 systematic review/meta-analytic studies identified, only three were not associated with an intervention or comorbidities (Cengelli et al. 2012; Vangeli et al. 2011; Zhang and Wang 2008). Two of the three remaining studies were identified as focused on a specific demographic group, but were reviewed for the extent to which variables studied were applicable to the wider population. One study focused on young people and variables specific to this group, such as living with parents and school variables (Cengelli et al. 2012). The other focused on Asian Americans and geared towards variables such acculturation and beliefs specific to the Asian American community. Consequently, both studies were excluded (Figure 2.2.). The remaining study by Vangeli and colleagues (Vangeli et al. 2011) was utilized to identify variables significantly associated with quit attempt and success in articles published before 1/1/2011.

2.2.2 Review of Research Studies and Survey Findings since January 1, 2011

Given the rapid changes in the tobacco-related legislative environment (M Tynan et al. 2011) and the changing smoking patterns of young people (Pierce, White, and Messer 2009), it is possible that new evidence has emerged about the variables that are associated with attempting to quit smoking and smoking cessation. Given the relatively short period of time that had passed since the completion of the prior systematic review (Vangeli et al. 2011), an update was feasible.

The systematic review identified in Part 1 of the literature review was updated to include all relevant literature published between 1/1/2011 and 12/31/2014 (Figure 2.2.2). The following **search terms** were used: smoking AND (cessation OR quit) AND predict* AND (population OR national OR international) (Vangeli et al. 2011) and **inclusion** and **exclusion**

criteria were the same as indicated above. The databases searched and the study selection criteria were consistent with those described in section 2.2.1.

2.2.2.1 Results of the review of research studies and surveys since January 1, 2011

Of 429 articles identified, title and abstract review showed only 16 were not associated with an intervention or comorbidities. These 16 studies were then assessed for the extent to which they met the other inclusion criteria. Five studies (Cheng et al. 2015; Fidler and West 2011; Ip et al. 2012; Kim 2014; Rafful et al. 2013) met all the inclusion criteria and the variables with significant association with quit attempt and cessation were extracted into evidence tables (Vangeli et al. 2011). Only two studies identified new variables: stress-level (Kim 2014), and urges to smoke (Fidler and West 2011). These were added to the list of variables for inclusion in the cluster analysis from Vangeli et al (Vangeli et al. 2011).

Figure 2.2.1 Flow Chart of Study Selection and Exclusion from Literature Review Part 1: Review of Synthesized Evidence

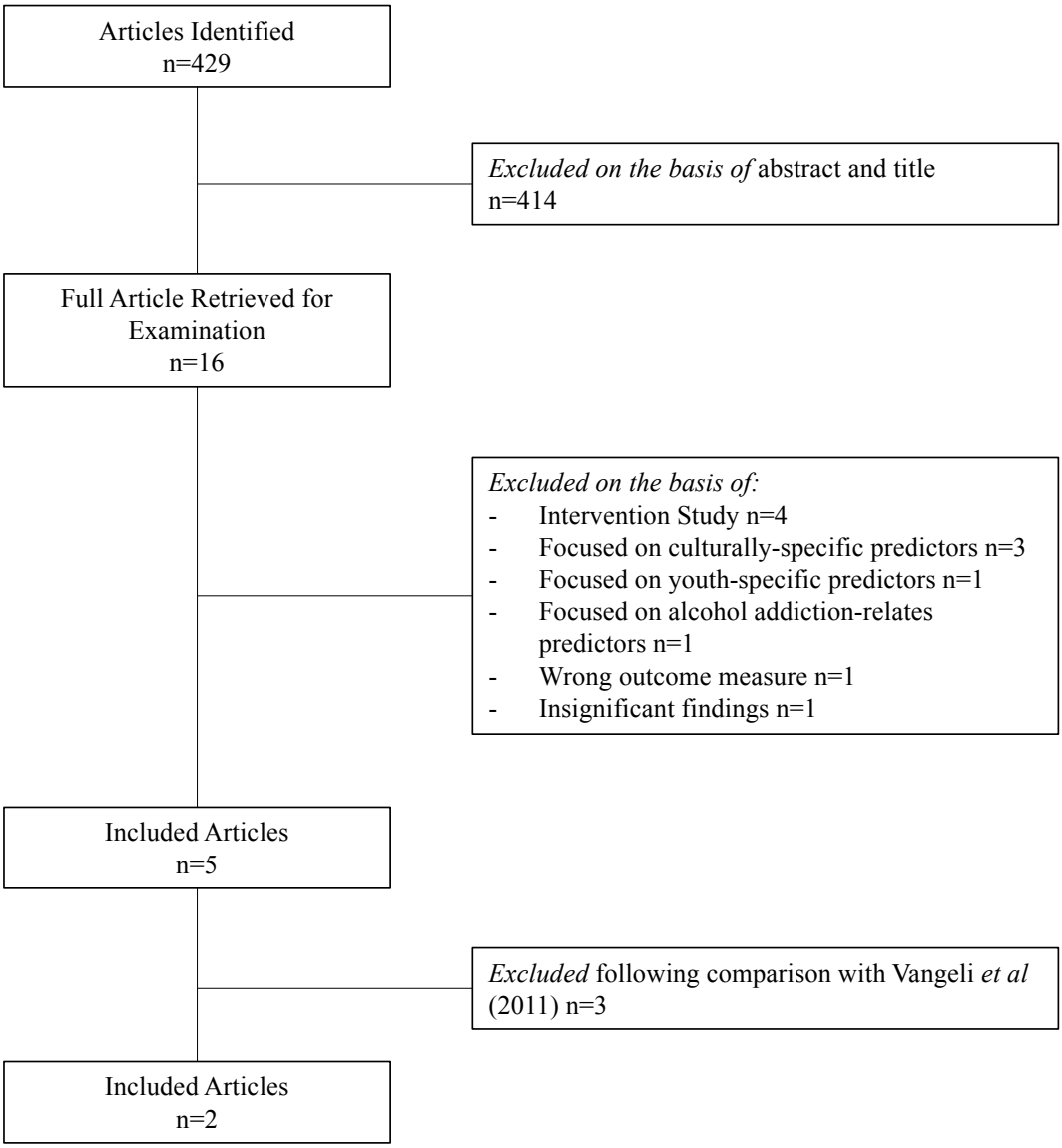

Figure 2.2.2 Flow Chart of Study Selection and Exclusion from Literature Review Part 2: Review of Studies and Survey Findings Since January 1, 2011.

2.3 Guidance Review

2.3.1 Introduction

Guidance and information about best practice have long been used to distil and disseminate research findings for use by practitioners and clinicians. Such "grey literature," is material that is not commercially published and so not identified in searches of electronic databases, but includes conference proceedings, dissertations, government publications, and committee reports (Bolderston 2008). This type of literature is commonly included in systematic reviews and in evidence assessment (National Institute for Health and Care Excellence 2014).

There are also additional sources of evidence from federal agencies and research or policy organizations. Such organizations publish guidance and synthesized evidence aiming to provide public health practitioners with resources that enable the translation of academic findings into actionable intervention and program plans. The sources included in this review were: Centers for Disease Control and Prevention. Best Practices for Comprehensive Tobacco Control Programs. Guidance document, US Preventive Services Task Force guidance, WHO Framework Convention on Tobacco Control (WHO FCTC), Cochrane Database, AHRQ/PHS Clinical Practice Guideline for Treating Tobacco Use and Dependence, and CDC and RWJ-sponsored County Health Rankings Program Database

2.3.2 Methods

The organizational website for each of the sources was visited and the tobacco section was navigated to using the site map. If a tobacco section was not easy to find, a search of the site for the term "tobacco" was undertaken. The returns were scanned for content relating to smoking cessation and evaluated according to the following **inclusion criteria**: evidence of significant association, general population sample (i.e., not recruited for particular clinical

conditions or demographics), adult participants (≥18 years of age), specifically examining predictors of quit attempts and/or specifically examining success in those who made a quit attempt. The following **exclusion criteria** were applied: individual study (i.e., not synthesized evidence), youth/pregnancy focused. The executive summary of each document meeting the inclusion criteria was assessed for relevance, which was defined as targeting an individual or interpersonal level variable with the desired outcome being a quit attempt or successful quit. The target variables for interventions described in the documents were then extracted into Table 2.2.1.

2.3.3 Results of the Guidance Review

All but one variable significantly associated with quit attempt and success identified in the guidance review had already been identified in the literature search. However, many variables identified in the literature were not covered in the guidance. This suggests that guidance is evidence-based, but not comprehensive.

Table 2.3.1 Constructs Identified in Grey Literature Review

Individual/interpersonal level outcome *Review Process*	**# of Studies**	**# of Relevant Studies**	**Perceived Harms**	**Perceived Benefits**	**Cravings**	**Intention to quit**	**Motivation to quit**	**Self efficacy to quit**	**Attitudes to smoking**	**Stress**	**Interpersonal Support**	**Quitting Cognitions**	**Health Insur. Cover***	**Quit Hx**
CDC Best Practices for Comprehensive Tobacco Control Programs Review Chapter III Cessation Interventions	1	1					x				x		x	x
USPSTF guidance#	2	2												
WHO. MPOWER. Toolkit for delivering the 5A's and 5R's brief tobacco interventions in primary care	1	1	x	x	x	x	x	x	x					
WHO. MPOWER. A guide for tobacco users to quit	1	1	X	x	x	x	x	x	x		x			
Cochrane DB All guidance documents filed under "Tobacco" in the "Tobacco, alcohol & drug" section.	39	22	x	x	x	x	x	x				x		
PHS Clinical Practice Guideline	1	1	x	x	x	x	x	x	x	x				
County Health Rankings Program Database All "scientifically evidenced" review documents filed under "Tobacco Use."	9	4	x	x	x	x	x	x						

x Denotes inclusion in logic model # Not specific enough without reviewing individual studies *Health Insurance Coverage

2.4 Program Review

2.4.1 Introduction

CDC's Best Practices for Comprehensive Tobacco Control Programs – 2014 (CDC 2014) is an evidence-based guide to help states plan and establish comprehensive tobacco control programs. Along with the Introduction to Process Evaluation in Tobacco Use Prevention and Control (Centers for Disease Control and Prevention 2008) guidance**,** the CDC advocates for states to produce a tobacco control plan that allows for the evaluation of inputs, activities, and outputs using a tobacco control logic model. Comprehensive tobacco control programs are published on state government websites.

2.4.2 Methods

State public health departments publish tobacco control strategies, which commonly include logic models to describe the mechanism of action of the smoking cessation programs they intend to implement. This allows state governments to specify measureable short, medium, and long-term goals from which they can demonstrate value.

In order to identify which variables were targeted in smoking cessation programs, a review of logic models published by state public health departments was conducted. The public health website for each state and D.C. was searched tor a tobacco control plan. Plans were reviewed for logic models with outcomes associated with smoking cessation. Only logic models that specifically targeted smoking cessation were used to extract individual and interpersonal-level variables targeted by states. Short and medium term outcome data was extracted and summarized in Table 2.4.1. In addition, each tobacco control plan was searched for "disparities" associated with tobacco control to identify, which *a priori* subgroups have been the most targeted in the implementation of tobacco control plans in the past, which are summarized in Table 2.4.2.

2.4.3 Results of the Program Review

Only 10 states had published cessation-specific models (Table 2.4.1). Increasing awareness and knowledge of harms and increasing quit attempts were the most prevalent outcome targets (Table 2.4.1). Race/Ethnicity was the most frequently cited "disparities" group, followed by low income and youth (Table 2.4.2).

Table 2.4.1 Constructs Targeted in State Tobacco Control Programs

	STATE									
Individual/ interpersonal level outcome	**GA**	**HI**	**ID**	**KS**	**MA**	**MD**	**MO**	**NJ**	**TX**	**WY**
Increased knowledge and skills to resist	x									
Increased number of quit attempts		x	x	x	x	x	x	x	x	
Intention to quit		x					x	x	x	x
Increase use of cessation services			x	x	x	x			x	
Increased awareness & knowledge of harms	x	x	x	x	x	x		x	x	x
Reduce average CPD										x

x denotes inclusion in logic model

Table 2.4.2 Disparities Stated in State Tobacco Control Programs

Minority group/State	AR	CO	CT	HI	ID	MA	MD	MO	MS	MT	NJ	NM	OH	OK	PA	SD	TX	VT	WI
Youth	x	x			x		x				x	x		x		x			x
Seniors											x	x		x		x			
Race/Ethnicity				x			x				x	x			x	x			x
Hispanic		x																	
African Americans			x		x				x								x		
Native Americans		x			x					x				x			x		
Asian Americans/Pacific Islanders		x																	
GLBT		x			x	x											x		
Low educational attainment			x	x	x			x									x		x
Gender											x	x				x	x		
Low income			x	x		x		x		x						x	x		x
People with low SES		x			x		x							x			x	x	
People in treatment for mental illness		x	x						x							x		x	x
People in treatment for substance abuse		x																x	x
People with disabilities		x				x									x		x		
Smokeless tobacco users		x																	
Migrant workers/Refugees					x														
Military																	x		

Table 2.4.2 Disparities Stated in State Tobacco Control Programs

Minority group/State	AR	CO	CT	HI	ID	MA	MD	MO	MS	MT	NJ	NM	OH	OK	PA	SD	TX	VT	WI
Medicare/Medicaid					x	x										x			
Uninsured						x													
WIC Women					x														
Pregnant women	x				x				x	x			x				x		

x denotes inclusion in logic model

2.5 Overall Findings

Following completion of the three reviews, the extracted variables were mapped to the variables in the 2010-11 Tobacco Use Supplement, the longitudinal dataset (see section 3.2.1 for summary of TUS-CPS data) that was used to segment the population (Figure 2.5.1 and Table 2.5.1).

Table 2.5.1 summarizes the results of the three evidence reviews. Apart from "skills to cope with cravings," all constructs identified from at least one source in the guidance and program reviews were also identified in the literature review, suggesting that the academic literature is guiding practice. However, there were gaps where the findings from the literature were not translated into practice. Race/Ethnicity, attitudes to smoking, knowledge about harms of smoking, intention to quit, and prior quit attempts were the only variables identified from all three sources (Table 2.5.1). No interpersonal level variables were identified in the non-academic literature, suggesting interpersonal variables are not a target for intervention or messaging in practice.

Table 2.5.1 Summary Results of Evidence Review of variables significantly associated with quit attempt &/or success

All variables identified in Vangeli et al (2011) unless otherwise referenced.

Constructs	Literature Review	Guidance Review	Program Review	TUS-CPS Dataset
Demographics				
Age	Yes	No	Yes	Yes
Education level	Yes	No	Yes	Yes
Gender	Yes	No	Yes	Yes
Income	Yes	No	Yes	Yes
Race/Ethnicity	Yes	Yes	Yes	Yes
Age of initiation	Yes	No	No	Yes
Marital status	Yes	No	No	Yes
Health Insurance	Yes	Yes	No	No
Quitting Cognitions				
Nicotine dependence	Yes	Yes	No	Yes
Opinion/Attitudes to smoking	Yes	Yes	Yes	Yes
Intention to quit	Yes	Yes	Yes	Yes
Self efficacy	Yes	Yes	No	Yes
Perceived Benefit	Yes	Yes	No	No
Perceived harms/Knowledge about harms	Yes	Yes	Yes	No
Wish/Desire to quit	Yes	Yes	No	No
Motivation to quit	Yes	Yes	No	Yes
Enjoyment of smoking	Yes	Yes	No	No
Cravings/Urge to smoke*	Yes	Yes	No	No
Skills to quit**	No	Yes	Yes	No

Table 2.5.1 Summary Results of Evidence Review of variables significantly associated with quit attempt &/or success

All variables identified in Vangeli et al (2011) unless otherwise referenced.

Constructs	Literature Review	Guidance Review	Program Review	TUS-CPS Dataset
Smoking Behavior				
CPD	Yes	No	Yes	Yes
Duration of longest quit attempt	Yes	No	No	Yes
Prior quit attempts	Yes	Yes	Yes	Yes
Prior quit attempt cessation aid use#	No	No	Yes	No
Lifestyle				
Stress Level***	Yes	Yes	No	No
Interpersonal Environment				
Home smoking ban	Yes	No	No	Yes
Interpersonal support	No	Yes	No	Yes

* (Fidler and West 2011) ** # *** (Kim 2014)

Variables to be used in next phase of analysis in BOLD

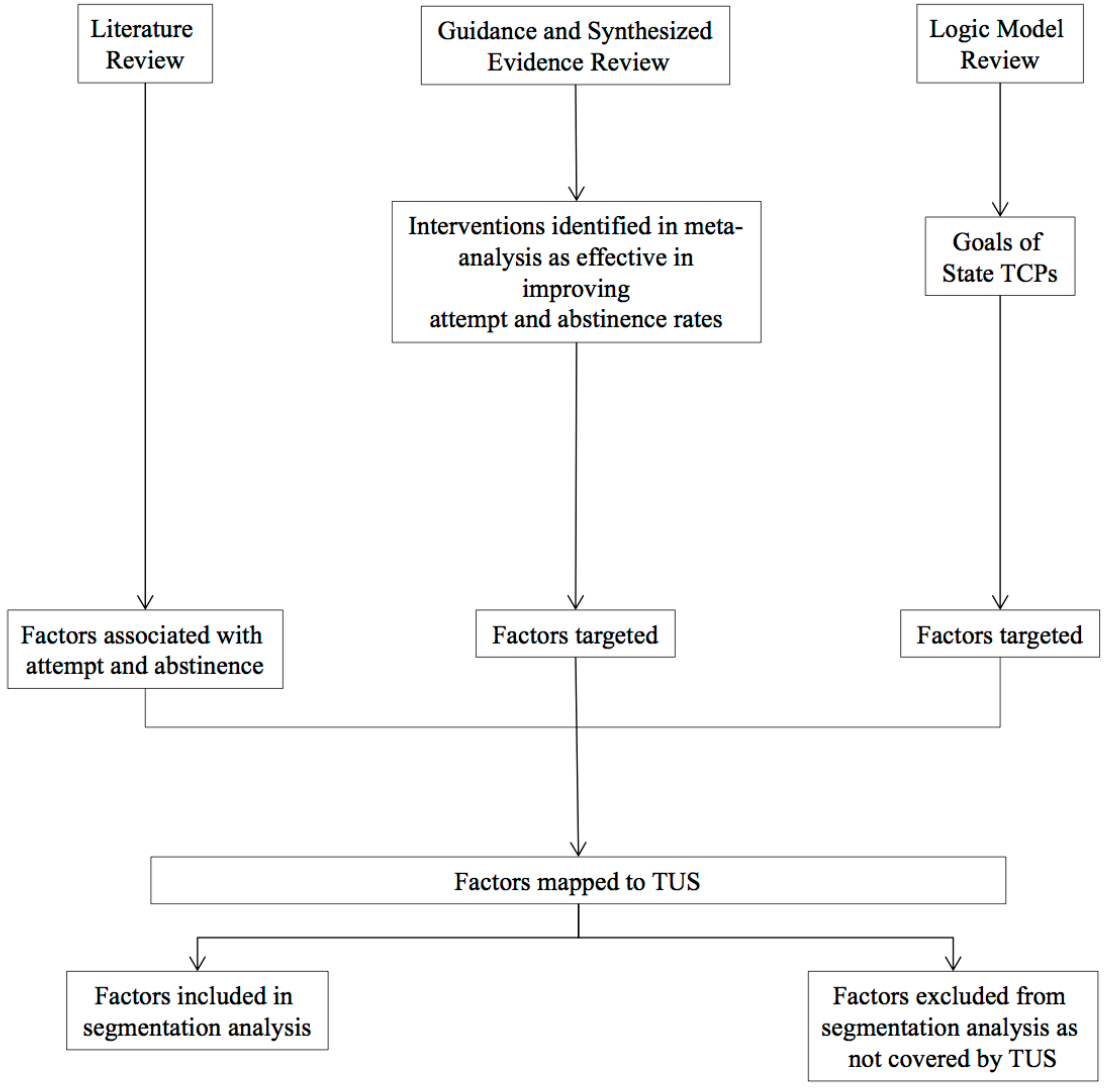

Figure 2.5.1 Mapping Constructs Identified in the Evidence Review to the TUS-CPS.

2.6 Conceptual Framework

The variables identified for the next phase of the study (Table 2.5.1) informed the analysis plan for the remainder of the dissertation. The variable set identified includes constructs that divide into obvious three categories that are important in health behavior theory and practice: personal variables, behavior variables, and environment variables (Figure 2.6.1). These categories are consistent with Bandura's social cognitive theory and the model of reciprocal determinism (Bandura 1986). Bandura's model of reciprocal determinism states that cognitive, affective, and biological factors interact with behavior patterns and environmental factors to influence each other in a bidirectional manner (Bandura 1986) (Figure 2.6.1).

In this study, the definition of environment is somewhat limited because only variables over which individuals have personal agency were included in the evidence review. Bandura acknowledges there are different types of environment: imposed, selected, and constructed, over which individuals have different levels of control (Bandura 1999). Not all types of environmental factors influence behavior all of the time. For the cluster analysis, only variables that exhibit individual level variation were sought. This meant that only selected and constructed environment variables were relevant. The theory of reciprocal determinism informed the underlying assumptions throughout the dissertation.

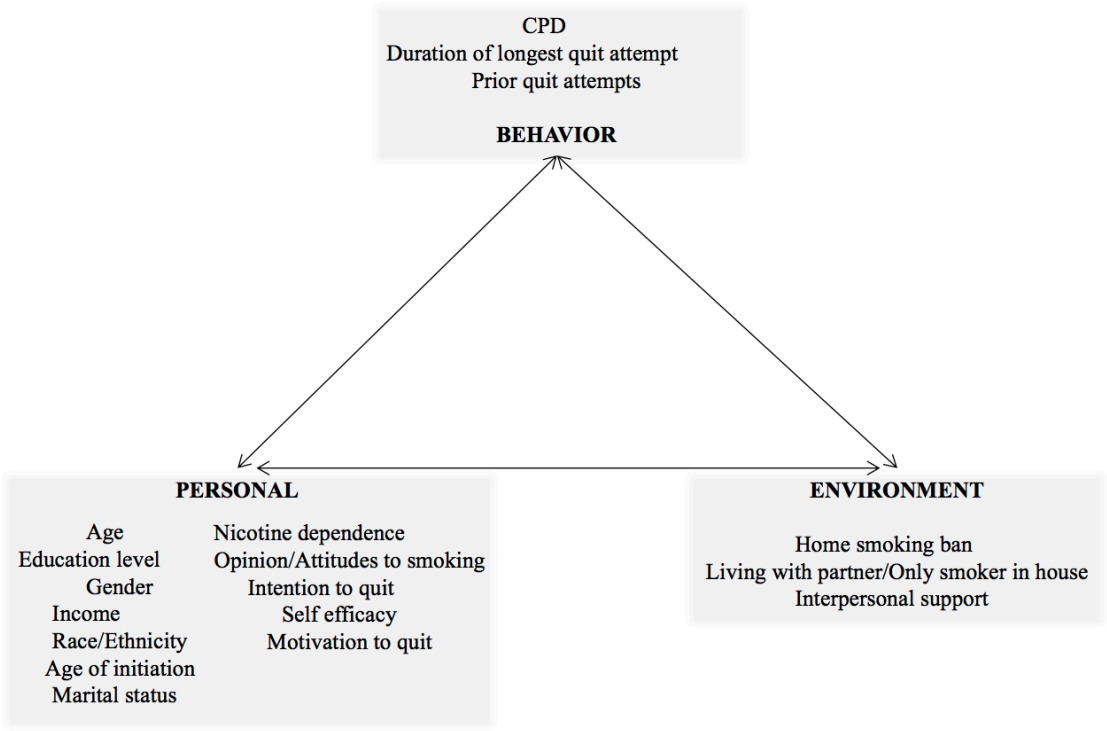

Figure 2.6.1 Conceptual Framework (adapted from Theory of Triadic Influence, (Bandura 1978)**)**

2.7 Using the Findings

All variables identified in one or more reviews and available in the TUS-CPS (Table 2.5.1.) were used in the next phase of the analysis to assess which of the variables identified are significantly associated with quit attempt and smoking cessation in unadjusted and adjusted analyses.

As a result of using a secondary data (TUS-CPS data) and having no control over the data items collected, not all relevant variables identified in the evidence review were available for the later steps in the study. This primarily effected cognition variables (Table 2.5.1). However, because "most environmental influences operate through cognitive processes" and the environmental variables that exhibit individual-level variation (Bandura 1999) are covered by the TUS-CPS data (Table 2.5.1), the environmental variables should reflect some of the information lost by excluding unavailable variables. This does, however, remain an important limitation of the evidence review.

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CHAPTER THREE

General Methods

3.1 RESEARCH OVERVIEW

The first stage of the research aimed to identify personal, behavioral, and personal environment variables independently significantly associated with cessation outcomes: attempting to quit smoking and smoking cessation. Firstly, an evidence review was conducted to identify variables associated with quit attempt and cessation from the literature (described in Chapter 2), followed by a multivariate logistic regression analysis to control for confounding factors and isolate the independent contribution of covariates to cessation outcomes. The variables independently associated with the outcomes were then used in a cluster analysis to segment the whole smoking population. Finally, the cluster groups were used to predict cessation outcomes and smoking-related behavior changes seen at the population level: change in smoking intensity and implementation of SFHs.

3.2 STUDY DATA AND POPULATION

3.2.1 Data

The primary data source for the study was the matched set of records from the May 2010 and May 2011 Tobacco Use Supplement of the U.S. Current Population Survey (TUS-CPS) (U.S. Department of Labor et al. 2006; US Department of Commerce 2015) The CPS is a monthly labor force survey that uses computer-assisted personal interview (CAPI) and computer-assisted telephone interview (CATI) to survey over 55,000 households per month across the United States (U.S. Department of Labor et al. 2006). The survey uses a probability sampling of the population aged 18 years and above in the civilian non-institutional United States, with independent samples selected from each state. The sampling design has two tiers. Firstly, the population is divided into primary sampling units (PSUs), which are constrained by state boundaries. PSUs are geographic areas that are homogeneous with respect to variables highly associated with unemployment, labor force, and socio-economic variables derived from

2000 Census data (U.S. Department of Labor et al. 2006). For the 2010/2011 data collection, the initial 2025 PSUs were grouped into strata within each state, of which 824 were selected for sampling. The sample included 72,000 households selected for monthly interview, of which 60,000 were occupied and almost 56,000 were reachable.

The CPS utilizes a panel design that surveys each household eight times over 16 months. Each household is surveyed for four consecutive months (months 1 through 4), is not surveyed in the following eight months (months 5 through 12), and is surveyed again for four consecutive months (months 12 through 16). This design results in a 75% month-to-month sample overlap and a 50% year-to-year sample overlap. This means that each month's sample is representative of the sampling population and sampling error is reduced by allowing for the use of a composite estimation procedure (U.S. Department of Labor et al. 2006).

Starting in 1992, the CPS-Tobacco Use Supplement (TUS-CPS), coordinated by the National Cancer Institute, added a supplement to the CPS to provide evaluative data for state-level tobacco control programs. This TUS-CPS has been conducted approximately every three years, with each wave consisting of a supplement to the CPS for three separate months chosen so they represent an independent sample of the CPS (thus the data are collected at 4 month intervals). In 2010-11, the design included an overlap sample so that the respondents first interviewed in May of 2010 were re-interviewed in May of 2011. There were 28,153 respondents in both May 2010 and May 2011, of which 18,499 were self-respondents at both baseline (May 2010) and follow-up (May 2011). This study only included data from respondents who supplied self-report data at both time points because proxy respondents were not asked all of the questions in the survey. Prior to undertaking analysis, the data was weighted (using provided weights from CPS), so the findings were representative of the 2000 Census distribution of age, gender, race/ethnicity, and state factors. In addition, replicate

weights were applied, which is a bootstrapping method that re-samples the population 160 times to derive variance estimates (US Department of Commerce 2015).

3.2.2 Study Population Inclusion and Exclusion Criteria

3.2.2.1 Inclusion Criteria

The study population included only respondents that indicated they were current smokers in May 2010 by answering "yes" to the question "Have you smoked at least 100 cigarettes in your entire life? And when subsequently asked "Do you now smoke cigarettes every day, some days, or not at all?" responded with either "every day" or "some days."

3.2.2.2 Exclusion Criteria

Respondents were excluded if they if they provided inconsistent answers to the following question: "Have you smoked at least 100 cigarettes in your entire life?" with "yes" on the first survey and "no" on the second survey. 1041 records were excluded for this reason and will be referred to as 'Reverters' throughout this study. Further analysis of the excluded respondents showed that the majority reported being former smokers at baseline and never smokers at follow-up (785, 75%; data not shown). Consequently, these records would not have met the aforementioned inclusion criteria, which identify current smokers at baseline, and their exclusion is not expected to impact the study. The remaining 256 respondents indicated smoking everyday or some days at baseline. These records would constitute 9% of the study sample, had they been included. However, because these respondents indicated never smoking at follow-up, they were not asked most of the questions posed to current and former smokers in May 2011. Responses to questions at follow-up are required to calculate quit attempt, success, change in cigarettes smoked per day, and smoke-free home implementation. Although it is not possible to identify whether these Reverters made a quit attempt, successfully quit, or made behavioral changes during the study, their baseline

characteristics can be used to assess the possible impact of excluding these records on the findings of the study (Table 3.2.1). At baseline, the Reverters were significantly more likely to be light smokers (<10 cigarettes per day (CPD)) and report low nicotine dependence (smoking their first cigarette more than 30 minutes after waking), but not more likely to have a smoke-free home (SFH). The most striking difference between the Reverters and the rest of the population was their race/ethnicity (R/E) profile. While overall 81% of respondents of the final study sample were non-Hispanic White (NHW), only 58% of the Reverters identified as NHW (Table 3.2.1). Had the Reverters been included in the study sample, they would have accounted for 25% of Hispanic respondents, 16% of Non-Hispanic Black (NHB) respondents, and 13% of Asian and Other (A and O) respondents. Consequently, excluding Reverters resulted in the minority groups being under-represented in the study sample. The importance of these differences for the findings of the study depends upon whether the intra-race/ethnicity (R/E) group variation of the excluded records was significantly different to those included in the final sample.

Comparison of the characteristics of the Reverters and the final sample by R/E suggests that excluding the Reverters is likely to bias the findings for the Asian and Other group the most because this R/E group exhibits the largest differences between the Reverters and the final sample (Table 3.2.2). For example, 78% of A and O Reverters reported low nicotine dependence, compared to 52% of A and O in the study sample, and 39% of A and O Reverters reported low nicotine dependence, compared to 19% of A and O in the study sample (Table 3.3.2). This is consistent with the finding that the survey was not well understood when translated into Asian languages (Willis et al. 2008). For example, 35.8% of those completing the survey in Cantonese and 34.8% of those completing in Vietnamese asked for clarification with the question “Have you smoked at least 100 cigarettes in your entire life?” This is

compared to 4.3% of those taking the survey in English (Willis et al. 2008). The Asian and Other Reverters appear to exhibit characteristics that have been associated with increased odds of quit attempt and success e.g., light smoking (<10 CPD), low dependence, and having a SFH. The general trend across all groups and variables is that Reverters exhibit pro-cessation variables at a higher rate than in the final sample, resulting in a likely under-reporting of cessation behaviors minority groups. This is a limitation of the study.

Given the comparatively pro-cessation characteristics of the Reverters as a group, it is feasible they are predominantly quitters. Reverters may have misheard the question or interpreted the question incorrectly. In minority groups, this could be the result of language or cultural barriers (Huer and Saenz 2003; McGorry 2000). Future research should ensure that this question is thoroughly tested in all R/E groups to prevent valuable information being lost due to lack of follow-up data.

Table 3.2.1 Univariate Analysis of Baseline Characteristics in Reverters and the Study Sample

Variable	Reverters n=256		Study Sample n=2569		p-value
Behaviors					
CPD					
<10	164	64%	1285	50%	0.000
10 to 19	25	10%	314	12%	
20+	67	26%	970	38%	
Dependence					
30 minutes or less	90	35%	1319	51%	0.000
More than 30 mins	166	65%	1250	49%	
Smoke-free Home					
Total Ban	132	52%	1122	44%	0.124
Partial Ban	54	21%	556	22%	
No Restrictions	70	27%	891	35%	
Demographics					
Race/Ethnicity					
Hispanic	46	18%	138	5%	0.000
Non Hispanic White	149	58%	2087	81%	
Non-Hispanic Black	43	17%	220	9%	
Asian & Other	18	7%	124	5%	
Age					
18 to 30	43	17%	319	12%	0.000
30 to 49	122	48%	1078	42%	
50 to 64	66	26%	917	36%	
65+	25	10%	255	10%	
Education Level					
Less than High School Diploma	55	21%	400	16%	0.000
High School Diploma	82	32%	1034	40%	
Some college/degree	74	29%	779	30%	
College graduate or higher	45	18%	356	14%	
Gender					
Male	125	49%	1202	47%	0.533
Female	131	51%	1367	53%	

Table 3.2.2 Comparison of Key Covariates in Reverters and in the Study Sample by Race/Ethnicity Group

Variable Level	Reverters n = 256			Study Sample n = 2569			Absolute Difference %*
	n	#	%	n	#	%	
Smoking Intensity: <10 CPD							
Hispanic	46	36	78%	138	103	75%	4%
Non-Hispanic White	149	73	49%	2087	910	44%	5%
Non-Hispanic Black	43	32	74%	220	152	69%	5%
Asian & Other	18	13	72%	124	79	64%	9%
Nicotine Dependence: More than 30 minutes							
Hispanic	46	39	85%	138	101	73%	12%
Non-Hispanic White	149	86	58%	2087	959	46%	12%
Non-Hispanic Black	43	25	58%	220	115	52%	6%
Asian & Other	18	14	78%	124	64	52%	26%
Age: 18-29							
Hispanic	46	8	17%	138	20	14%	3%
Non-Hispanic White	149	24	16%	2087	262	13%	4%
Non-Hispanic Black	43	4	9%	220	14	6%	3%
Asian & Other	18	7	39%	124	23	19%	20%
Age: 65+							
Hispanic	46	1	2%	138	9	7%	-4%
Non-Hispanic White	149	20	13%	2087	234	11%	2%
Non-Hispanic Black	43	4	9%	220	29	13%	-4%
Asian & Other	18	0	0%	124	8	6%	-6%
Education: Less than High School							
Hispanic	46	18	39%	138	42	30%	9%
Non-Hispanic White	149	19	13%	2087	276	13%	0%
Non-Hispanic Black	43	17	40%	220	62	28%	11%
Asian & Other	18	1	6%	124	20	16%	-11%
Education: College Graduate							
Hispanic	46	5	11%	138	13	9%	1%
Non-Hispanic White	149	31	21%	2087	293	14%	7%
Non-Hispanic Black	43	1	2%	220	21	10%	-7%
Asian & Other	18	8	44%	124	29	23%	21%

* p values not calculated due to small cell sizes

3.3 MEASURES

3.3.1 Behavior Variables

3.3.1.1 Quitting Behavior Variables

Quit attempt

A quit attempt (QA) was defined from the following questions on the follow-up survey when asked of people that indicated current smoking at baseline: "During the past 12 months, have you tried to quit smoking completely?" and "During the past 12 months, have you stopped smoking for one day or longer because you were trying to quit smoking?" Respondents who answered "yes" to both questions were categorized as having made a QA during the study.

30+ day abstinence

An early marker of successful cessation, 30 day or longer abstinence at follow-up, was defined as being a self-report smoker at baseline and reporting abstinence for at least 30 days at follow-up. 30+ day abstinence (30D-A) is associated with smoking behavior prior to making a quit attempt and with 12-month abstinence (Gilpin and Pierce 1994). Pierce *et al.* (Gilpin and Pierce 1994) reported that heavy, dependent smokers with a poor quitting history were the least likely to achieve 30D-A (5.8%), while low dependence smokers with a strong baseline quitting history were the most likely (25%). Overall, the vast majority of people did not achieve 30+ day abstinence at follow-up (Pierce, Farkas, and Ilpin 1998). In the context of the study follow-up period being only 12 months, using a 30+ day abstinence measure is practical for sample size, because it allows successful quit attempts initiated at any point during the first 11 months of the study to be captured. Using a 90+ day abstinence as the cessation measure, which has stronger predictive validity than 30-day (Gilpin, Pierce, and Farkas 1997), would potentially eliminate a quarter of successful quit attempts from the

analysis (because it is not possible for anyone starting a quit attempt in the last 90 days of the study to meet the criteria before the follow-up survey). Such a choice would severely limit the study's power to draw conclusions. The choice of 30D-A as a measure of cessation represents a defensible balance between an appropriate quitting success measure and study power.

Prior quit attempts

Quitting history was measured using baseline questions: "During the past 12 months, have you tried to quit smoking completely?" and "Have you ever tried to quit smoking completely?" Smokers were categorized as recent quitters (quit attempt in the previous year), non-recent quitters (last quit attempt over 12 months), and never quitters (those who reported never having tried to quit) (Hyland et al. 2006).

3.3.1.2 Smoking Behavior Variable

Cigarettes per day

Smoking intensity at baseline was measured as the average number of cigarettes smoked per day (CPD). Daily smokers were asked "On average, how many cigarettes do you now smoke a day?" Non-daily smokers were asked: "On how many of the past 30 days did you smoke cigarettes?" and then "On average, when you smoked, about how many cigarettes did you smoke a day?" For some day smokers, the latter two questions were then used to calculate average daily consumption. Responses for all groups were then categorized into: <10 CPD, 10-19 CPD, or 20+ CPD. In the analysis of mean consumption levels, to avoid the undue influence of outliers, consumption was trimmed to a maximum of 40 CPD (the 95th percentile) (Messer, Mills, et al. 2008).

3.3.2 Personal Variables

3.3.2.1 Nicotine Dependence

Time to first cigarette after waking is a good indicator of nicotine dependence (Baker et al. 2007; Heatherton et al. 1991). Current daily smokers (and some day smokers) were asked: "On the days that you smoke, how long after you wake up do you typically smoke your first cigarette of the day?" For both groups, those smoking their first cigarette within the first 30 minutes after waking, were defined as 'high dependence' and those smoking their first cigarette after more than 30 minutes 'low dependence' (Fagerström 2003). 60% of everyday smokers and 14% of some day smokers were coded to high dependence.

3.3.2.2 Demographic Variables

Age

The age variable was calculated from responses to the CPS question "What is your date of birth?" and verified by asking "As of last week, that would make you x years old. Is that correct?" (United States Census Bureau 2009) Individual years of age were coded into one of four categories, consistent with previous similar studies. Categories used were: 18-29, 30-49, 50-64, and 65+ (Pierce, White, and Messer 2009).

Education level

Education level was calculated from responses to the CPS question "What is the highest level of school you have completed or the highest degree you have received?" The valid responses, from 'less than 1st grade' to 'doctoral degree,' were recoded into four categories consistent with previous similar studies. (Pierce et al. 2009) Categories used were: Less than High School Grad, High School Grad, Some College, and College Grad or higher.

Gender

Gender was asked assigned by the CPS interviewer, unless it was unclear, in which case the respondent was asked: "What is your sex?" The response categories allowed by the survey instrument were male or female (United States Census Bureau 2009).

Race/Ethnicity

Race/ethnicity was derived from the question "Are you of Hispanic, Latino, or Spanish origin?" (United States Census Bureau 2009). Those who answered "yes" were coded to Hispanic (H) race/ethnicity. All respondents, including those coded to Hispanic, were asked: "I am going to read you a list of five race categories. You may choose one or more races. For this survey, Hispanic origin is not a race. Are you White; Black or Non-Hispanic Black; American Indian or Alaska Native; Asian; OR Native Hawaiian or Other Pacific Islander? (United States Census Bureau 2009). The responses of those who had answered "Hispanic" were excluded from the coding. For all other respondents, categories were assigned consistent with previous similar studies (Messer, Trinidad, et al. 2008). Those who answered "White" were coded to Non-Hispanic White (NHW), "Black or Non-Hispanic Black" to Non-Hispanic Black (NHB), and "American Indian or Alaska Native; Asian or Native Hawaiian or Other Pacific Islander" to Asian or other (A and O) (Messer, Trinidad, et al. 2008).

3.3.2.3 Quitting Cognition Variables

The TUS-CPS asks four questions under the heading "Stages of Change." The questions cover: intention to quit, interest in quitting, and personal assessment of likelihood of successful quit if attempted (US Department of Commerce 2015).

Intention to quit

The measurement of intention to quit was constructed using two questions from the baseline TUS-CPS (US Department of Commerce 2015) 'Are you seriously considering quitting smoking in the next 6 months?' And, 'Are you planning to quit in the next 30 days?' The answers to these two questions were combined into a variable with three categories: planning to quit in the next 30 days, in the next 6 months, and not planning to quit or unknown (Biener and Abrams 1991; Farkas et al. 1996; Pizacani et al. 2004).

Interest in quitting

The interest in quitting variable was constructed using responses to the baseline TUS-CPS question, 'overall, on a scale from 1 to 10 where 1 is not at all interested and 10 is extremely interested, how interested are you in quitting smoking'? The responses were grouped, with 1 to 3 coded as 'low interest,' 4 to 7 'moderate interest,' and 8 to 10 'high interest' (DiClemente et al. 1991). Those who answered: "Don't know," refused, or did not respond were coded to 'low interest.' Those reporting interest = 1 made up the 'not interested in quitting" category in the self-efficacy variable described below.

Personal Assessment of Likelihood of Successful Quit if Attempted (Self-efficacy)

The personal assessment of likelihood of successfully quitting if an attempt is made is in essence a quit self-efficacy variable. It was constructed using responses to the question 'If you did try to quit smoking altogether, how likely do you think you would be to succeed – not at all, a little likely, somewhat likely, or very likely?' Not at all was coded into 'low self-efficacy,' a little and somewhat likely was coded into 'moderate self-efficacy,' and very likely into 'high self-efficacy.' Due to the skip pattern of the survey, the respondents that indicated an interest in quitting = 1 were not asked the self-efficacy question. They were coded to a separate category 'Not interest in quitting.'

3.3.3 Environment Variables

3.3.3.1 Personal Environmental Variables

Smoke-free home (SFH)

Respondents were questioned about their home smoking environment at baseline. They were asked, "Which statement best describes the rules about smoking in your home: No one is allowed to smoke anywhere, smoking is allowed in some places or at some times, or smoking is permitted anywhere." Those who indicated that no one is allowed to smoke anywhere were classified as having a SFH (Farkas et al. 1999; Messer, Mills, et al. 2008).

Living with other smokers

The 'living with other smokers' variable measured whether the respondent was living with at least one other adult smoker (Farkas et al. 1999; Messer, Mills, et al. 2008). This was calculated by first identifying TUS-CPS respondents that lived in the same home, using the household identifier variable, then ascertaining how many members of the household reported being current smokers, using the aforementioned current smoking criteria.

3.3.3.2 Policy Environment Variables

The evidence review detailed in the previous chapter identified personal, behavioral, and personal environment variables associated with smoking cessation behavior. Therefore, the scope of the evidence review precluded variables from the broader environment. However, the theory of triadic reciprocal determinism posits that the broader environmental variables, which influence and are influenced by behaviors and personal factors, cover a broader range of environments than the personal environment (Bandura 1999). Bandura states that the environment is comprised of three types of environmental structures: the imposed environment, the selected environment, and the constructed environment (Bandura 1997). Policy environment variables are imposed on people, for example excise taxes and smoke-free

laws. Although smokers have no control over the policies, they are able to control how they react and adapt their behaviors to the imposed rules. Therefore, consistent with the conceptual framework for the study, it was important to identify salient policy level variables and control for them in the multi-level analysis.

Smoking-related policy environment variables were identified from the Healthy People 2020 (HP2020) goals from the section entitled, Tobacco-related Social and Environmental Changes (CDC 2014; U.S. Department of Health and Human Services Office of Disease Prevention and Health Promotion 2010). As a robust framework was used by the Government to identify changeable variables for inclusion in the HP2020 Tobacco Use goals; all of the goals were reviewed to identify relevance to the analysis and availability of data (U.S. Department of Health and Human Services Office of Disease Prevention and Health Promotion 2010). The review identified the following variables for which data was available: secondhand smoke exposure in non-smokers that work indoors, smoke-free indoor workplace policies, smoke-free public places policies, state tax on tobacco products.

State tax on tobacco products

State tobacco tax rates for each state in 2010 were sourced from the Tax Foundation (Henchman and Drenkard 2012). Tax rates were coded into a categorical variable because, in the general adult population, significant increases in tobacco taxes have been shown to elicit significant improvements in public health (Chaloupka, Yurekli, and Fong 2012).

The tax rates were categorized into three groups: 'Low Tax,' 'Medium Tax,' and 'High Tax.' While tax rates are often categorized by tertiles, which divides the data set into three groups with equal numbers of observations per category (Bonnie, Stratton, and Wallace 2007), these may not produce the most appropriate cut points given the positive skew of the distribution of tax rates. Applying the tertile method of cut-point calculation to the 2010 state

tobacco tax data, the High Tax category includes tax rates from $1.36 - $3.46, which is very heterogeneous and covers 61% of the range of values of tax rate (Table 3.3.1 and Figure 3.3.1).

An alternative to using the tertile method is using an equal interval scheme to assign cut-points at equal distances along the range of tax rate values (Cao, Ge, and Wang 2013). It has been argued that this is more appropriate because a large volume of research has been conducted to understand the impact of actual and relative cigarette price changes on smoking and quitting behavior (Bader, Boisclair, and Ferrence 2011; Chaloupka et al. 2002; Chaloupka and Warner 2000; Hatzenbuehler et al. 2011). Applying equal interval cut-points, 49% of smokers were assigned to the Low Tax category with only 13% being assigned to the High Tax category (Table 3.3.1 and Figure 3.3.1). This resulted in considerable heterogeneity with respect to tax in the Low Tax group.

Given the limitations of the two previously described methods and the desire to limit the variable to three categories to preserve power for further analysis, the frequency distribution was graphed to identify any natural cut-points in the distribution, consistent with the Jenks natural breaks optimization method (Jenks 1967) (Figure 3.3.2). The distribution had two points at which the gradient of the cumulative frequency line clearly changed. Such a change in gradient represents the tax rate values becoming more common (a steeper gradient) or less common (a shallower gradient). In a 3-category variable, this method allows the cut-points to reflect the 'common' values in one category, where the gradient is steep, and to distinguish the common values from those above or below this group. Using natural break cut-points, the mode category was Medium Tax, but the High and Low categories remained large and somewhat diverse. The final category cut points, derived using the natural break method,

were: Low Tax $0 - $0.91, Medium Tax $0.92 - $1.78, and High Tax $1.79 - $3.46 (Table 3.3.1). Tax Group by state is listed in Table 3.3.2.

Smoke-free laws

Smoke-free laws (SFLs) commonly apply to three categories of venue: 100% Smoke-free Non-Hospitality Workplaces, such as public and private non-hospitality workplaces, offices, factories, and retail stores, 100% Smoke-free Restaurants, including any attached bar in the restaurant, and 100% Smoke-free Freestanding Bars (ANRF 2014). Using the detailed classification system reported by Americans for Non-smokers Rights (ANRF, 2014), the date that a state effected a 100% smoke-free restaurant law or the date the sum of local laws reached 100% coverage was used to assign the year smoke-free laws were effected in a state. Having 100% state coverage of smoke-free restaurants (SFR) was chosen as the measure of SFLs as they are the most prevalent type of smoke-free law. In addition, with one exception, all states that have 100% SFLs applicable to any location have smoke-free restaurants. The existence of smoke-free laws was measured by the effective date of 100% smoke-free provision in restaurants. States were coded to one of two categories: '100% SFRs in 2010' or 'Not 100% SFRs' in 2010. 33 states and D.C. were assigned to 100% SFRs and 17 to Not 100% SFRs (Table 3.3.2). This corroborates with the high coverage (80% of employees or more) of indoor workers reporting 100% smoke-free policies (36 states and D.C.) and lower coverage (less than 80% of employees) of indoor workers reporting 100% smoke-free policies (14 states; data not shown). SFR group by state is listed in Table 3.3.2.

3.3.4 Quit-Specific Variables

A number of questions in the TUS-CPS asked at follow-up only to those who made an attempt between baseline and follow-up. They related to the quitting behavior during the study period (US Department of Commerce Census Bureau 2012). The evidence review (chapter 2)

identified two such variables covered by TUS-CPS questions only asked to those making a quit attempt.

Interpersonal support

Smokers that made a quit attempt during the study were asked whether they used "help or support from friends or family?" during the last time they tried to quit. Those answering yes were coded as 'received social support.' All other responses were coded to 'no help or support from friends or family.

Pharmaceutical quit aids

Smokers that made a quit attempt, successful or unsuccessful, were asked whether they used Chantix, Varenicline, Zyban, Bupropion, Wellbutrin, or another prescription drugs during their last quit attempt. They were also asked whether they used nicotine patches, nicotine gum or lozenge, or nicotine nasal spray or inhaler during their last attempt. If one or more of any of these products were used, the respondent was coded as having 'used pharma aids' during their last quit attempt during the study period. All other responses were coded to 'did not use pharma aids.'

Table 3.3.1 Tax Rate Category Assignment by Classification Methodology

	A. Population Tertile Classification Method			B. Equal Interval Classification Method			C. Natural Breaks Classification Method		
N	837	957	1033	1395	1073	359	837	1356	634
% Of population*	30%	34%	37%	49%	38%	13%	30%	48%	22%
Tax Rate Cut Point ($)	0.84	0.52	2.1	1.15	1.09	1.22	0.84	0.87	1.75
Category Range ($)	0 - 0.84	0.85 - 1.36	1.37 - 3.46	0 - 1.15	1.16 - 2.24	2.25 - 3.46	0 - 0.91	0.92 - 1.78	1.79 - 3.46
% Of Overall Range of Tax Rates	24%	15%	61%	33%	32%	35%	24%	25%	51%
Tax Group Category Assigned	Low	Medium	High	Low	Medium	High	Low	Medium	High

* Tertile and value-based cut-points are approximate, as all smokers within a state have the same tax rate and cannot be split between two tax rate categories.

Table 3.3.2 Proportion of Population Covered by 100% Smoke-free Restaurant Laws in 2010 and Tax Group by State

State	State SFR Law	% Covered by Local SFR Laws	100% SFLs in 2010	Tax Group	State	State SFR Law	% Covered by Local SFR Laws	100% SFLs in 2010	Tax Group
AK	No	50%	No	Medium	MN	Yes	*	Yes	High
AL	No	15%	No	Low	MO	No	0.16	No	Low
AR	No	5%	No	Medium	MS	No	0.23	No	Low
AZ	Yes	*	Yes	High	MT	Yes	*	Yes	High
CA	Yes	*	Yes	Medium	NC	Yes	*	Yes	Low
CO	Yes	*	Yes	Low	ND	No	0.36	No	Low
CT	Yes	*	Yes	High	NE	Yes	*	Yes	Low
DC	No	100%	Yes	High	NH	Yes	*	Yes	High
DE	Yes	*	Yes	High	NJ	Yes	*	Yes	High
FL	Yes	*	Yes	Medium	NM	Yes	*	Yes	Medium
GA	No	5%	No	Low	NV	Yes	*	Yes	Low
HI	Yes	*	Yes	High	NY	Yes	*	Yes	High
IA	Yes	*	Yes	High	OH	Yes	*	Yes	Medium
ID	Yes	*	Yes	Low	OK	No	0%	No	Medium
IL	Yes	*	Yes	Medium	OR	Yes	*	Yes	Medium
IN	No	29%	No	Medium	PA	No	12%	No	High
KS	Yes	*	Yes	High	RI	No	100%	Yes	High
KY	No	31%	No	Low	SC	No	31%	No	Low
LA	Yes	*	Yes	Low	SD	Yes	*	Yes	High
MA	Yes	*	Yes	High	TN	No	0%	No	Low
MD	Yes	*	Yes	High	TX	No	36%	No	High
ME	Yes	*	Yes	High	UT	Yes	*	Yes	High
MI	Yes	*	Yes	High	VA	No	3%	No	Low

Table 3.3.2 Proportion of Population Covered by 100% Smoke-free Restaurant Laws in 2010 and Tax Group by State

State	State SFR Law	% Covered by Local SFR Laws	100% SFLs in 2010	Tax Group	State	State SFR Law	% Covered by Local SFR Laws	100% SFLs in 2010	Tax Group
VT	Yes	*	Yes	High	WV	No	60%	No	Low
WA	Yes	*	Yes	High	WY	No	21%	No	Low
WI	Yes	*	Yes	High					

* 100% of population covered by state law.

Source: ANRF, 2014

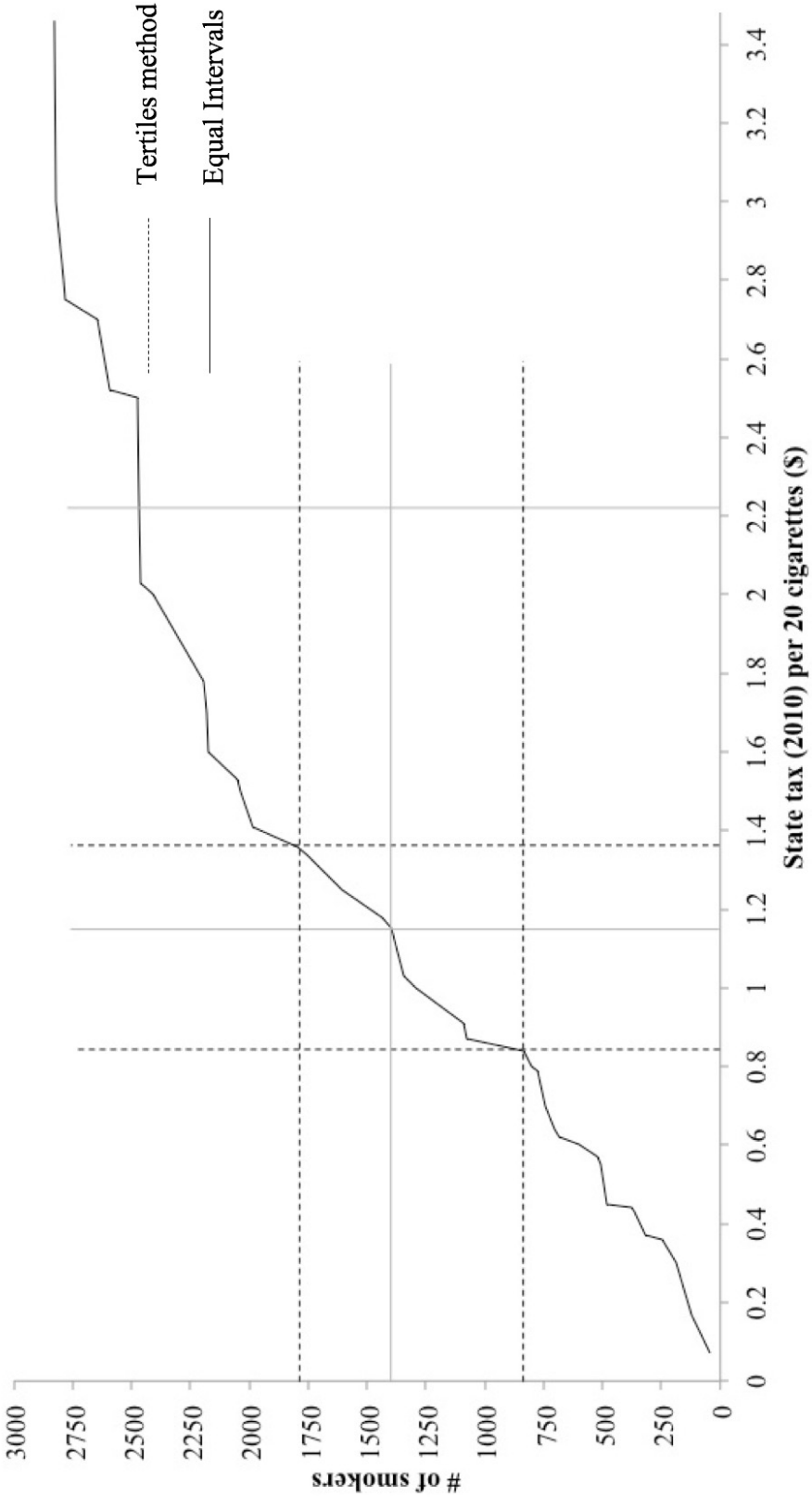

Figure 3.3.1: Cumulative frequency of state tobacco tax and cut-points using tertile and equal interval methods

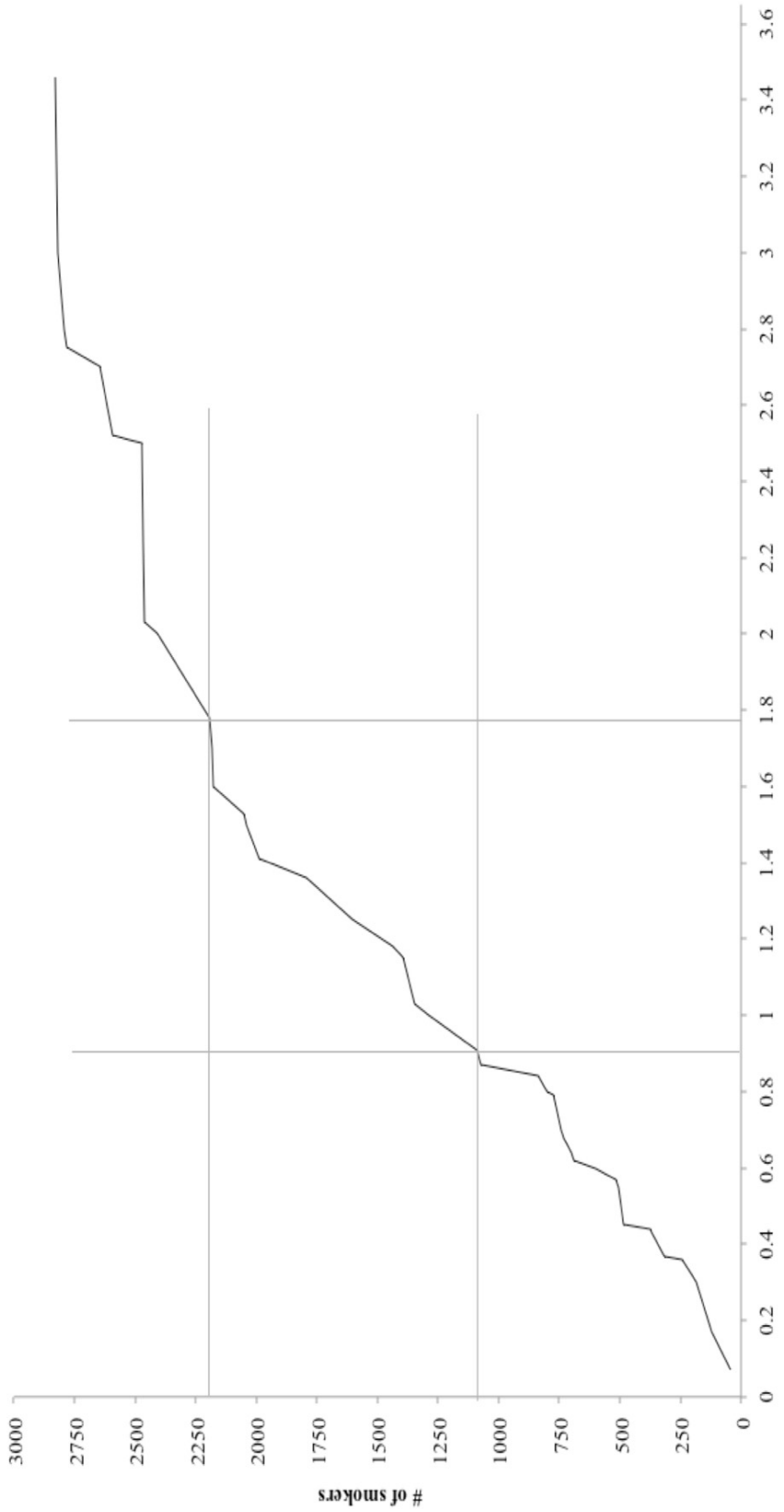

Figure 3.3.2: Cumulative frequency of state tobacco tax and cut points derived using natural breaks method

3.3.5 Limitations of Measures

There are a number of limitations associated with the measures described above. Firstly, it has long been established that poor recall of non-salient life events over a number of months can result in under-reporting (Casey, Masuda, and Holmes 1967). This is true of the recall of quit attempts, which are known to be inaccurate over relatively short periods of time (Berg et al. 2010; Gilpin and Pierce 1994). For example, Gilpin and Pierce showed that self-reported relapse rates were 18% higher at 4-month recall than 9-12 month recall (Gilpin and Pierce 1994). This was especially apparent for quit attempts that lasted less than one week. Given that the TUS-CPS question used to define quit attempt in this study asks the respondent to recall attempts of one day or longer over the last 12 months, quit attempts are likely to be under-reported in this study. This limitation also applied to quit attempts prior to baseline. The result of under reporting of quit attempts would be a lower quit attempt rate, which would also result in a higher proportion of those who made an attempt achieving 30D-A at follow-up. The potential impact of under-reporting of quit attempts prior to baseline is an inflation in the 'never tried to quit' category and reduction in the number who tried to quit in the past. Given the effect of time on recall, it is likely that the recall of quit attempts more than 12 months prior to baseline would be the most biased (Gilpin and Pierce 1994).

Secondly, the follow up period of the study, 12 months, has significant limitations when estimating whether a quit attempt has been made and its duration. It is well known that quit attempts have a very high failure rate, with cross-sectional surveys indicating some 40% of smokers making a quit attempt in any year (Zhu et al. 2012), and longitudinal surveys indicating that less than 3% are successful (Center for Disease Control 2014). A recent study estimated the average number of quit attempts before a smoker is successful ranged from 6 to 142 depending on assumptions.

The third limitation relates to the nicotine dependence proxy variable, time to first cigarette. It has been noted that the question "On the days that you smoke, how long after you wake up do you typically smoke your first cigarette of the day?" commonly requires probing to obtain a valid answer (Willis et al. 2008). Although respondents were asked how many minutes after they wake up they have their first cigarette, many answered qualitatively and have to be questioned further to translate their responses, such as "after breakfast," into minutes. This probing is undertaken less commonly when the TUS-CPS is administered in a language other than English (Willis et al. 2008), which could bias the responses for non-English speaking respondents.

The quitting cognition variables have a number of limitations. Personal assessment of likelihood of quit success if an attempt is made (self-efficacy (SE)) was not asked to individuals who expressed no interest in quitting, which introduces selection bias and is a limitation of the study. By excluding those who are not interested in quitting it is difficult to elucidate the constructs of interest in quitting and self-belief in ability to quit smoking. This is especially problematic for light and intermittent smokers, who have the propensity to believe their smoking behavior does not carry significant health risks (Schane, Ling, and Glantz 2010), which could translate into no interest in quitting, but a high self-efficacy. Results from Levy and colleagues (Levy, Biener, and Rigotti 2009) present empirical evidence to suggest such a combination of quitting cognitions exist. As the trend for more people move into smoking <10 CPD continues (Ahmed et al. 2016), understanding this sub-population will become increasingly important. Another issue with the self-efficacy variable is the validity of a single item generic question for the measurement of the construct. Bandura states that "self-efficacy has many domains and the construction of sound efficacy scales relies on a good conceptual analysis of the relevant domain of functioning" (Bandura 2006). The situation-

specific nature of self-efficacy described by Bandura is not captured in the TUS-CPS. Lastly, the timing of the administration of the self-efficacy instrument has been shown to impact the predictive validity of SE on future smoking (Gwaltney et al. 2009), with the strength of the relationship between being significantly stronger if measured after the start of a quit attempt rather than prior to the start of a quit attempt. The quit interest variable was also associated with validity issues in some demographic groups, which is especially important as it sets the sampling frame for the self-efficacy questionnaire. Willis and colleagues have shown that some race/ethnicity groups do not understand the wording of the TUS-CPS interest in quitting question and more frequently ask for clarification and give invalid responses compared to other groups (Willis et al. 2008). Lastly, quitting cognition variables are subject to rapid change within an individual over short periods of time. Hughes *et al* described how self-reported quit intentions changed in up to a third of participants over 30 days (Hughes et al. 2005), while Peters *et al* reported that smokers' interest in quitting can change quickly (Peters and Hughes 2009).

Finally, it is a limitation that the social support variable is only asked to those who make a quit attempt during the study and is constrained to their last quit attempt as opposed to any quit attempt during the study. This means the majority of the respondents have missing data, making the variable unsuitable for inclusion in cluster analysis.

3.4 ANALYSIS

3.4.1 Univariate Analysis

Univariate analysis was undertaken using all of the variables identified for use in the cluster analysis by the evidence review and the policy environment variables identified in the review of the Healthy People 2020 documents (U.S. Department of Health and Human Services Office of Disease Prevention and Health Promotion 2010). Chi-squared tests were

used to identify whether each variable is significantly associated with QA and 30D-A. The cell values for each crosstab were assessed for potential issues with small sample size. Only variables significantly associated with the outcome variable ($p<0.05$) were tested for confounding in the model-building phase of the analysis apart.

3.4.2 Regression Analyses

3.4.2.1 Model Building

Model building was hypothesis-driven; meaning initial selection of outcome variable and covariates were based on the hypothesis being tested. Due to the large number of potentially important confounders, a sequential variable selection technique was used to identify the remaining independent variables. Stepwise regression is the most popular sequential technique and, like all sequential techniques, is unlikely to produce a model with multicollinearity (Glantz and Slinker 2001).

3.4.2.2 Statistical Methods

All estimates, 95% confidence intervals (CIs), and p-values were weighted by the published TUS-CPS overlap sample weights, which account for the sampling design as well as estimated under-coverage and nonresponse (Davis 2007). Analyses used SAS version 9.1 statistical software PROC SURVEYFREQ for weighted percentages and Rao-Scott weighted chi-square tests (Rao and Scott 1987).

Testing for Collinearity

Collinearity of covariates identified in the evidence review was assessed using the variance inflation factor (Glantz and Slinker 2001), in accordance with the recommendations of the SPSS (IBM SPSS Statistics Technote 2014). SPSS calculates “tolerance” in the PROC REG function, which is an indication of the proportion of the variance in the predictor that cannot be accounted for by the other predictors. The variance inflation factor (VIF) is

(1 / tolerance) and variables whose VIF values are greater than 10 were investigated further (IDRE 2012).

3.4.3 Cluster Analysis

Cluster analysis was used to segment the smoking population by profiles of personal, behavioral, and personal environment factors. Detailed methods used to derive the cluster solution and characterize the clusters are in earlier in this 3.

The usefulness of the cluster groups is dependent on the variable being associated with the study outcomes of interest, namely QAs and 30D-A. Standard parametric procedures, outlined in section 3.4.1, were used to evaluate the unadjusted association of the cluster group variable with the outcome variables. The predictive validity of the cluster variable on the outcome variables was also tested using regression techniques described in section 3.4.2. Analyses were undertaken using SAS version 9.1 statistical software using PROC SURVEYLOGISTIC (Rao and Scott 1987).

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CHAPTER FOUR

Empirical Selection of Candidate Variables for Cluster Analysis

4.1 INTRODUCTION

4.1.1 Purpose of Analysis

The analyses presented in this chapter aim to ascertain which of the variables identified in the evidence review (Chapter 2) are the most appropriate candidate variables for cluster analysis. The associations between the variables identified in the review and the study outcome measures, quit attempt (QA) and successful 30+ day quit (30D-A), were empirically tested in both unadjusted and adjusted analyses.

Identifying candidate variables for cluster analysis in a theory-driven, evidenced-based empirical manner should ensure that any underlying structures identified by the cluster analysis are relevant to smoking cessation outcomes and meaningful for future tobacco control research and potentially practice.

4.1.2 Importance of Evidence-Based Candidate Variable Selection for Cluster Analysis

Cluster analysis is a data-driven methodology, which derives groups that are primarily interpreted with respect to the variables used to define them (Brusco 2004). Consequently, it is important that the set of candidate variables used in the cluster modeling process are relevant to the outcomes for which the cluster solution is intended to add knowledge, in this case, smoking cessation in current smokers.

In well-funded, long-established research areas, such as tobacco control research, relevant variables have been identified empirically through years of study. This body of evidence, along with a review of the variables that have been prioritized in the translation of academic research into practice, provided the information required to ensure that only smoking cessation-relevant variables are included in the cluster analysis.

4.1.3 Identifying Variables Independently Associated with Outcomes

Cluster analysis applies statistical methods to identify patterns in a dataset and its purpose is not to predict a specified outcome. Instead it aims to discover the underlying structure of unlabeled data to form natural groups, or clusters (Cummins 2008). In the absence of theory-driven hypotheses, it is advisable for the selection of candidate variables to be driven by a conceptual framework (Everitt et al. 2011). According to the social cognitive theory-based conceptual framework detailed in Chapter 2, Figure 2.6, personal, behavioral, and personal environment variables are likely to be significantly associated with the study outcomes, the quitting behaviors QA and 30D-A. Given the posited bi-directionality of the relationships between the variables identified in the evidence review, empirically evaluating the variables that have an independent association with quitting behaviors should identify an appropriate set of candidate variables for cluster analysis.

Many of the studies included in the evidence review were conducted in the 1990s and early 2000s, since then the tobacco environment and patterns of smoking-related behavior have continued to change (CDC 2007; Centers for Disease Control and Prevention 2015; Messer et al. 2008; Pierce et al. 2010; Pierce, White, and Messer 2009; Zhang, Cowling, and Tang 2010). Applying the conceptual framework, changes in environment and behavior will influence other behavioral and environmental factors as well as personal factors. This could influence the relationship between variables associated with quitting behaviors in the past and current quitting behaviors. One potential reason for a change in the relationship between an independent variable and QA and 30D-A is a reduction in the variation across the population as some cognitions and behaviors have become widespread due to social diffusion (Bandura 1986; Borland et al. 2006). By identifying candidate variables for the cluster analysis that continue to be independently associated with cessation behavior, the clusters were more likely

to predict QA and 30D-A and provide useful insights into the influence of characteristics that commonly co-occur in the smoking population on cessation.

4.2 CHAPTER-SPECIFIC METHODS

4.2.1 Selection of Variables for Cluster Analysis from Regression Results

Following univariate and multivariate analyses evaluating the adjusted and unadjusted associations of variables identified in the evidence review with QA and 30D-A, variables were selected as candidate variables for cluster analysis based on their statistical significance in the adjusted models predicting quit attempt and quit success. Independent variables in each model with a p-value of ≤ 0.25 in one or both models were selected. A p-value of 0.25 was selected as the "F-to-Enter"-type value (Bendel and Afifi 1977), which is used in variable selection in stepwise regression because the goal of the first round of variable reduction is to be liberal and inclusive while maintaining a workable set of variables (Bursac et al. 2008). Another reason to use an inclusive approach to variable selection was the reliance on a single, albeit nationally collected and representative, dataset (TUS-CPS). If a conservative p-value inclusion criterion was used, it is possible that the criterion could be met in one dataset, but fail to be met in another. By using a higher value criterion for inclusion, it is unlikely that a variable that is truly independently associated with the outcome variables would fail to pass the criterion test in any dataset.

The variables with a p-value > 0.05 that were not dropped during the model building process were included because they significantly contributed to the pseudo-R2 value and tests for confounding and interaction were negative. All demographic variables were selected as candidate variables because, not only are demographic variables traditionally used in epidemiological and public health research and practice, they also reflect a host of latent lifestyle and culture variables, which are not measured in the TUS-CPS (Edberg 2011).

4.2.2 Exclusion of Variables from Cluster Analysis

In order to conduct meaningful cluster analysis, it is important to use variables that show individual level variation with respect to the outcomes of interest, are not highly changeable, do not have a large amount of missing data, and are measured in a valid way in the study dataset (Everitt et al. 2011). By selecting only personal, behavioral, and personal environment variables as candidate variables, only factors that individuals have some degree of personal agency over are included (Bandura 1999). This avoids nesting, where large numbers of the population are assigned the same value for a variable, reducing overall variation. Examples of nesting variables include smoke-free laws and tobacco taxation, which apply the same value to every person residing in the same state. Although quitting cognitions are important in social cognitive theory (SCT), there are a number of consistency issues and validity issues associated with the cognition variables in the TUS-CPS, which make them unsuitable for use as clustering variables. These issues are discussed in detail in Section 3.3.5.

Two variables were excluded from the cluster analysis because they were only applicable to those who made a quit attempt. These were use of pharmaceutical quit aid during last quit attempt and social support during last quit attempt. All variables excluded from the cluster candidate variable set were controlled for in subsequent analyses where appropriate and were tested for their association with the cluster group variable in subsequent analyses.

4.3 RESULTS

4.3.1 Findings: Univariate Analysis

4.3.1.1 Smoking behaviors

In unadjusted analyses, smoking behavior, namely CPD and nicotine dependence, were associated with both quit attempt and success (Table 4.3.1, 4.3.2). There was a negative association between cigarette consumption and quit attempt. Those reporting the lowest CPD

were most likely to attempt to quit (56.0%, +/- 3.3), the moderate intensity group were less likely to attempt than the low intensity group (46.8%, +/- 2.9), but more likely than the high intensity smokers (37.6%, +/- 2.7) (Table 4.3.1). A threshold effect was evident for the 30D-A outcome, with the lightest smokers being more likely to report 30D-A at follow-up (33.2%, +/- 3.2), than the moderate and high intensity groups, who were almost equally likely to be successful (30.0%, +/- 4.1 and 23.5%, +/- 4.3 respectively) (Table 4.3.2). Lower nicotine dependence was associated with an increased likelihood of a quit attempt. Those reporting they smoked their first cigarette more than 30 minutes after waking up (low dependence) were more likely to attempt to quit (51.8%, +/- 2.7), compared to those smoking in the first 30 minutes (41.7%, +/- 1.9) (Table 4.3.1). The same trend was evident for smoking cessation, with the low dependence smokers being more likely to quit during the study period than high dependence smokers (34.0%, +/- 3.1 and 24.3%, +/- 3.2 respectively) (Table 4.3.2).

4.3.1.2 Timing of last quit attempt

Timing of last quit attempt, namely the timing of the last failed quit attempt, was strongly associated with quit attempt and success (Tables 4.3.1 and 4.3.2). Smokers reporting a quit attempt in the 12 months prior to baseline were more likely to try to quit during the study (62.0%, +/- 2.6 vs. 36.2%, +/- 3.2 and 32.7%, +/- 2.53 respectively), but less likely to be successful (24.4%, +/- 2.8 vs. 34.9%, +/- 5.8 and 37.3%, +/- 4.3 respectively), than respondents who last tried to quit more than 12 months ago, or had never tried to do so (Tables 4.3.1 and 4.3.2).

4.3.1.3 Quitting cognitions

In unadjusted analyses, interest in quitting and intention to quit were strongly associated with both quit attempt and success. However, only quit intention was significantly associated with cessation (Table 4.3.1). There was a positive association between intention to

quit and quit attempt. Those reporting a plan to quit in the next 30 days were most likely to attempt to quit during the study (70.9%, +/- 4.1), those planning to quit in the next 2-6 months were less likely to attempt than smokers with more immediate intentions, (53.5%, +/- 3.8), but more likely than smokers with no quit intentions (36.3%, +/- 1.9) (Table 4.3.2). Smokers with no intention to quit were the most likely to be successful if they made an attempt (33.1%, +/- 3.0), and those with an intention to quit in the next 30 days were more likely to report 30D-A than those with a 2-6 month intention (27.8%, +/- 5.0 and 24.0%, +/- 4.0, respectively) (Table 4.3.1). There was also a positive association between interest in quitting and quit attempt. Those with a high interest in quitting were most likely to attempt to quit (65.4%, +/- 3.20), those with moderate interest were less likely to attempt than the high interest group, (41.8%, +/- 2.7), but more likely smokers not interested in quitting (30.1%, +/- 2.7) (Table 4.3.1).

4.3.1.4 Demographics

In unadjusted analyses, age group, education level, and gender were associated with both quit attempt and success. Race/Ethnicity was not associated with either outcome measure (Table 4.3.1). There was a negative association between age and quit attempt, with the three younger groups the most likely to report QA (18-29 year olds: 54.4% +/- 4.6 vs. 30-49 year olds: 45.7%, +/- 2.3, 50-64 year olds: 43.4%, +/-, 2.5, and 65+ year olds 38.6%, +/- 4.5 respectively) (Table 4.3.1). However, the youngest and oldest groups were the most likely to be successful if they made an attempt (18-29 year olds: 34.8% +/- 6.3 and 65+ year olds: 33.7%, +/- 7.5 respectively vs. 30-49 year olds: 28.7%, +/- 3.2 and 50-64 year olds: 23.7%, +/- 3.1) (Table 4.3.2). Any college education was associated with a higher likelihood of both quit attempt and success (Tables 4.3.1 and 4.3.2). 46.7% (+/- 4.5) of respondents with a college degree and 50.2% (+/- 2.8) of respondents with some college made an attempt to quit during the study period, while 44.9% (+/- 4.2) of respondents with less than a high school diploma

and 43.8% (+/- 2.4) of respondents that finished education after high school did so. Cessation success varied with educational group, with each higher level of education associated with a higher success rate (College Graduate: 41.3% +/- 6.2, Some College: 37.8%, +/- 4.3, High School Graduate: 22.9%, +/-, 2.9, and Less than High School Graduate: 17.2%, +/- 4.5 respectively) (Table 4.3.2). Although, women were more likely to make a quit attempt than men (Female: 49.3% +/- 2.0 vs. Male: 43.8%, +/- 2.4 respectively) (Table 4.3.1), success per attempt was higher in males (Male: 32.1% +/- 3.5 vs. Female: 26.4%, +/- 2.5 respectively) (Table 4.3.2).

4.3.1.5 Personal environment

In unadjusted analyses, both a total home smoking ban and being the only smoker in the household were associated with an increased probability of making a quit attempt and it being successful (Tables 4.3.1 and 4.3.2). While 52.6% (+/- 2.6) of respondents with a total home smoking ban at baseline made an attempt during the study, only 41.1% (+/- 2. 1) of those without a total ban did so in the same period (Table 4.3.1). 35.3% (+/- 3.1) of smokers with a total home smoking ban that attempted to quit during the study achieved 30 or more days of abstinence at follow-up, while only 22.9% (+/- 2.8) without a total ban reported cessation (Table 4.3.2). 48.2% (+/- 1.9) of respondents living with non-smokers made an attempt during the study, while 42.4% (+/- 3.2) of those living with other smokers did so in the same period (Table 4.3.1). 30.7% (+/- 2.4) of smokers that attempted to quit during the study and reported living with non-smokers, achieved 30 or more days of abstinence at follow-up, while only 25.8% (+/- 4.1) without a total ban reported cessation (Tables 4.3.1 and 4.3.2).

4.3.1.6 Social and environmental level variables

There was a direct association between the amount of state-levied tobacco tax and quit attempt, with respondents living in high tax states the most likely to make a quit attempt

(3.60% +/- 3.7) (Table 4.3.1). 46.1% (+/- 2.3) of smokers living moderate tobacco tax states made a quit attempt during the study, while 41.5% (+/- 2.6) of those living in low tobacco tax states did so in the same period (Table 4.3.1). However, state-levied tobacco tax was not significantly associated with at least 30 days of abstinence at follow-up (Table 4.3.2). In unadjusted analyses, living in a state that had implemented 100% smoke-free laws in restaurants by 2010 was associated with an increased probability of making a quit attempt, but was not associated with an attempt being successful (48.5% +/- 1.9 vs. 42.7%, +/- 2.6 respectively) (Tables 4.3.1 and 4.3.2).

4.3.1.7 Quit specific variables

Any kind of pharmaceutical quit aid during the last quit attempt was associated with a decreased probability of success (16.0% +/- 2.8 vs. 34%, +/- 2.6) (Table 4.3.2). In unadjusted analyses, having social supports during the last quit attempt was also associated with an increased probability of success (31.9% +/- 2.7 vs. 23.0%, +/- 3.4) (Table 4.3.2)

Table 4.3.1 Univariate Analysis of Quit Attempt During Study (n=2569)

	Population		Total Reporting QA at follow-up (n=1181)			
Independent Variables	%	CI (+/-)	N	%	CI (+/-)	Sig.
Smoking Behavior						
Baseline consumption						
< 10 CPD	31.8%	1.6	453	56.0%	3.3	***
10-19 CPD	31.4%	1.6	377	46.8%	2.9	
20+ CPD	36.8%	1.6	351	37.6%	2.7	
Baseline time to first cigarette						
Within 30 min	54.1%	1.7	588	41.7%	1.9	***
> 30 min	45.9%	1.7	593	51.8%	2.7	
Timing of last quit attempt						
Attempt within last 12 mo.	44.3%	1.7	720	62.0%	2.6	
Attempt >12mo. ago	18.3%	1.0	177	36.2%	3.2	
Never tried to quit	37.4%	1.6	284	32.7%	2.5	***
Quitting Cognitions						
Baseline quitting intention						
Plan to quit in next month	16.5%	1.3	288	70.9%	4.1	***
Plan to quit in next 2-6 month	22.8%	1.4	337	55.3%	3.8	
No intent to quit	60.6%	1.8	556	36.3%	1.9	
Baseline interest in quitting						
High interest	33.8%	1.6	573	65.4%	3.2	
Moderate interest	31.9%	1.6	335	41.8%	2.7	
Low interest	34.3%	1.6	273	30.1%	2.7	***
Baseline self-efficacy						
High self-efficacy	22%	0.7	335	58.5	1.9	**
Moderate self-efficacy	45%	0.9	587	50.5	1.2	
Low self-efficacy	7%	0.4	59	33.9	2.9	
No interest in quitting	25%	0.7	200	31.5	1.5	
Demographics						
Race/Ethnicity						
Hispanic	8.9%	1.1	69	45.9%	5.7	NS
Non-Hispanic White	76.3%	1.4	942	46.2%	1.8	
Non-Hispanic Black	10.2%	1.0	112	46.6%	5.1	
Asian/Other	4.7%	0.6	58	49.8%	6.9	
Gender						
Male	53.8%	1.5	517	43.8%	2.4	**
Female	46.2%	1.5	664	49.3%	2.0	

Table 4.3.1 Univariate Analysis of Quit Attempt During Study (n=2569)

	Population		Total Reporting QA at follow-up (n=1181)			
Independent Variables	%	CI (+/-)	N	%	CI (+/-)	Sig.
Age						
18-29	22.3%	1.6	174	54.4%	4.6	***
30-49	39.8%	1.6	510	45.7%	2.3	
50-64	29.6%	1.2	399	43.4%	2.5	
65+	8.3%	0.7	98	38.6%	4.5	
Education						
< H. S. grad	17.3%	1.2	179	44.9%	4.2	**
H.S. grad	39.4%	1.5	453	43.8%	2.4	
Some college	30.8%	1.6	383	50.2%	2.8	
College grad	12.5%	1.0	166	46.7%	4.5	
Personal Environment						
Baseline home smoking ban						
No total ban	54.4%	1.6	594	41.1%	2.1	***
Total ban	45.6%	1.6	587	52.6%	2.6	
Lives with other smokers						
Sole smoker	68.1%	1.8	854	48.2%	1.9	**
Other smokers in HH	31.9%	1.8	327	42.4%	3.2	
Social Environment						
2010 Tobacco Tax						
High tax	21.7%	1.3	332	53.6%	3.7	***
Moderate tax	47.7%	1.9	502	46.1%	2.3	
Low tax	30.7%	1.7	347	41.5%	2.6	
2010 Restaurant ban						
Smoke-free	63.1%	1.8	814	48.5%	1.9	
Not Yet Implemented	36.9%	1.8	367	42.7%	2.6	***

NS not significant

Table 4.3.2 Univariate Analysis of Successful Quit During Study (n=1181)

	Population	Total reporting 30D-A at follow-up (n=328)			
Independent Variables	%	N	%	CI (+/-	Sig.
Smoking Behavior					
Baseline consumption					
< 10 CPD	38.4%	148	33.2	3.2	**
10-19 CPD	31.9%	99	30.0	4.1	
20+ CPD	29.7%	81	23.5	4.3	
Baseline time to first cigarette					
Within 30 min	49.8%	138	24.3	3.2	***
> 30 min	50.2%	190	34.0	3.1	
Timing of last quit attempt					
Attempt within last 12 mo.	61.0%	170	24.4	2.8	***
Attempt >12mo. ago	15.0%	62	34.9	5.8	
Never tried to quit	24.0%	96	37.3	4.3	
Quitting Cognitions					
Baseline quitting intention					
Plan to quit in next month	24.4%	78	27.8	5.0	**
Plan to quit in next 2-6 month	28.5%	76	24.0	4.0	
No intent to quit	47.1%	174	33.1	3.0	
Baseline interest in quitting					
High interest	48.5%	143	28.3	3.6	NS
Moderate interest	28.4%	103	29.8	4.4	
Low interest	20.5%	82	54.0	8.9	
Self-efficacy					
High self-efficacy	28.4%	99	9.6	0.8	**
Moderate self-efficacy	49.7%	154	13.3	0.9	
Low self-efficacy	5.0%	15	1.1	0.2	
No interest in quitting	16.9%	60	5.3	0.6	
Demographics					
Race/Ethnicity					
Hispanic	5.8%	21	31.2	7.9	NS
Non-Hispanic White	79.8%	267	29.8	2.4	
Non-Hispanic Black	9.5%	24	21.1	5.4	
Asian/Other	4.9%	16	35.5	11.5	

Table 4.3.2 Univariate Analysis of Successful Quit During Study (n=1181)

	Population	Total reporting 30D-A at follow-up (n=328)			
Independent Variables	%	N	%	CI (+/-	Sig.
Age					
18-29	14.7%	61	34.8	6.3	**
30-49	43.2%	137	28.7	3.2	
50-64	33.8%	97	23.7	3.1	
65+	8.3%	33	33.7	7.5	
Education					
< H. S. grad	15.2%	35	17.2	4.5	***
H.S. grad	38.4%	99	22.9	2.9	
Some college	32.4%	131	37.8	4.3	
College grad	14.1%	63	41.3	6.2	
Gender					
Male	43.8%	154	32.1	3.5	*
Female	56.2%	174	26.4	2.5	
Personal Environment					
Baseline home smoking ban					
No total ban	50.3%	136	22.9	2.8	***
Total ban	49.7%	192	35.3	3.1	
Lives with other smokers					
Sole smoker	72.3%	251	30.7	2.4	*
Other smokers in HH	27.7%	77	25.8	4.1	
Quitting-specific Personal variables					
Used pharma during study					
Yes	87.7%	259	16.0	2.8	***
No	12.3%	69	34.0	2.6	
Social support for quit					
Yes	86.3%	244	31.9	2.7	***
No	13.7%	84	23.0	3.4	
Social Environment					
2010 Taxes					
High tax	28.1%	96	29.9	4.4	NS
Moderate tax	42.5%	142	28.9	3.3	
Low tax	29.4%	90	29.4	4.2	
2010 Restaurant ban					NS
Smoke-free	68.9%	229	29.2	2.4	
Not Yet Implemented	31.1%	99	29.3	4.0	

* <.05 ** <.01 ***<.001 NS Not Significant

4.3.2 Findings: Multivariate Analysis

4.3.2.1 Factors associated with Quit Attempt

In adjusted analyses, light smokers (<10 CPD) were significantly more likely to attempt to quit than heavy smokers (20+ CPD) (AOR 1.29; 95% C.I. 1.03, 1.61; p=0.03), but this was not true for moderate smokers (10-19 CPD) (p=0.31) (Table 4.3.3). Smokers reporting a quit attempt in the year prior to the study were significantly more likely to attempt to quit than those who had never tried to quit (AOR 2.05; 95% C.I. 1.69, 2.47; p<0.0001).

Those who intended to quit in the next month at baseline were more likely to attempt to quit during the study period than those with no intention to quit (AOR 1.77; 95% C.I. 1.38, 2.27; p<0.0001), as were those who stated a high interested in quitting at (AOR 2.15; 95% C.I. 1.71, 2.70; p<0.0001). Among the demographic variables, only age and gender were significantly associated with quit attempt at the 5% level. Smokers aged 30 or older were significantly less likely to make a quit attempt than those aged 18-29. Men were significantly less likely to make a quit attempt during the study period than women (Table 4.3.3). Both personal environment variables were associated with quit attempt. Smokers with a total indoor smoking ban at home and being the only smoker in the household (AOR 1.19; 95% C.I. 1.00, 1.40; p=0.045 and AOR 1.26; 95% C.I. 1.06, 1.50; p=0.008 respectively) were more likely to report QA at follow-up (Table 4.3.3). At the policy level, living in a state with high state-levied tobacco tax was associated with higher odds of attempting to quit than those living in a state with low state-levied tobacco tax (AOR 1.60; 95% C.I. 1.29, 2.00; p<0.0001) (Table 4.3.3).

At the 25% level, smokers that reported having their first cigarette more than 30 min after waking up were significantly more likely to attempt to quit than those who smoke within 30 minutes (AOR 1.10; 95% C.I. 0.94, 1.29; p=0.245) (Table 4.3.3). Those who intended to

quit in the next 2-6 months at baseline were more likely to attempt to quit during the study period than those with no intention to quit (AOR 1.19; 95% C.I. 0.97, 1.46; p=0.890). Among the demographic variables, only Race/Ethnicity was associated at the inclusion criteria level of 25%, with smokers identifying as Hispanic less likely to make a quit attempt than Non-Hispanic White smokers (AOR 0.78; 95% C.I. 0.60, 1.03; p=0.075) (Table 4.3.3).

4.3.2.2 Factors associated with 30D-A

In contrast to the association of smoking intensity and quit attempt, moderate smokers (10-19 CPD) were significantly more likely to report 30D-A at follow-up than heavy smokers (20+ CPD) (AOR 1.40; 95% C.I. 1.00, 1.96; p=0.047), but this was not true for light (<10 CPD) smokers (p=0.41) (Table 4.3.4). Smokers that attempted to quit during the study and smokers who reported a quit attempt in the year prior to baseline were significantly less likely to achieve abstinence for 30+ days at follow-up than those who had never tried to quit (AOR 0.47; 95% C.I. 0.35, 0.63; p<0.0001). Those who intended quit in the next 2-6 months at baseline were significantly less likely to achieve 30+ day abstinence at follow-up than those with no intention to quit (AOR 0.67; 95% C.I. 0.50, 0.90; p=0.007). Among the demographic variables, only education level was significantly associated with 30-day or longer abstinence at the 5% level (Table 4.3.4). Smokers with at least a high school diploma were significantly more likely to be abstinent than those with less than a high school diploma (Table 4.3.4). Both personal environment variables, a total indoor smoking ban at home and being the only smoker in the household, were associated with 30D-A at follow-up (AOR 1.67; 95% C.I. 1.31, 2.12; p<.0001 and AOR 1.34; 95% C.I. 1.05, 1.71; p=0.020 respectively) (Table 4.3.4). Among the variables only relevant to those who made a quit attempt, only use of a pharmaceutical aid was significant at the 5% level, with those using any type of

pharmaceutical smoking cessation product significantly less likely to be abstinent (AOR 0.40; 95% C.I. 0.31, 0.53; p<.0001).

At the 25% level, smokers that reported having their first cigarette more than 30 min after waking up (high nicotine dependence) were significantly more likely to report 30D-A at follow-up than those who smoke within 30 minutes (AOR 1.22; 95% C.I. 0.93, 1.59; p=0.143) (Table 4.3.4). Those who intended quit in the next 2-6 months at baseline were less likely to be abstinent at follow-up than those with no intention to quit (AOR 0.67; 95% C.I. 0.50, 0.90; p=0.0075). However, those who stated a high interest in quitting at baseline were more likely to achieve 30D-A than smokers stating they were not interested (AOR 1.50; 95% C.I. 0.99, 2.26; p=0.053) (Table 4.3.4). Among the demographic variables, age and gender were significantly associated with quit attempt at the 25% level. Smokers between 50 and 64 years of age were significantly less likely to make a quit attempt than those aged 18-29. Men were more likely to make a quit attempt during the study period than women (Table 4.3.4).

4.3.3 Variables Selected for Cluster Analysis

Nine variables met the inclusion criteria, (personal, behavioral, or person environment variable, no systematically missing data, valid measure), to be used as candidate variables in the cluster analysis. The final set of variables selected is detailed in Table 4.3.5.

Table 4.3.3 Logistic Regression Predicting Quit Attempt

	Predicting Quit Attempt (n=2569)			
Independent Variables	OR	Confidence limits		P-value
Smoking Behavior				
Baseline consumption				
< 10 CPD	1.29	1.03	1.61	**0.0283**
10-19 CPD	1.11	0.91	1.34	0.3071
20 + CPD	Ref.			
Baseline time to first cigarette				
> 30 mins	1.1	0.94	1.29	*0.2453*
Within first 30 mins	Ref.			
Timing of last quit attempt				
Made attempt within last 12 months	2.05	1.69	2.48	**0.0000**
Made attempt, > 12 months ago	1.07	0.87	1.32	0.5056
Never attempted to quit	Ref.			
Quitting Cognitions				
Quitting intention				
Plan to quit in next month	1.77	1.38	2.27	**0.0000**
Plan to quit in next 2-6 months	1.19	0.97	1.46	*0.0890*
No intention to quit	Ref.			
Interest in quitting				
High interest	2.15	1.71	2.70	**0.0000**
Moderate interest	1.12	0.92	1.36	0.2608
Low interest	Ref.			
Demographics				
Race/Ethnicity				
Hispanic	0.78	0.60	1.03	*0.0749*
Non-Hispanic White	Ref.			
Non-Hispanic Black	0.9	0.71	1.16	0.4255
Asian/Other	1.03	0.74	1.44	0.8405
Age				
18-29	Ref.			
30-49	0.7	0.55	0.87	**0.0014**
50-64	0.71	0.57	0.9	**0.0039**
65+	0.59	0.44	0.79	**0.0003**

Table 4.3.3 Logistic Regression Predicting Quit Attempt

	Predicting Quit Attempt (n=2569)			
Independent Variables	OR	Confidence limits		P-value
Education				
Less than High school grad	Ref.			
High school grad	0.86	0.68	1.07	*0.1634*
Some college	1.04	0.84	1.29	0.7462
College grad	0.91	0.68	1.2	0.4852
Gender				
Male	0.83	0.72	0.95	**0.0081**
Female	Ref.			
Personal Environment				
Baseline home smoking ban				
No total ban	Ref.			
Total ban	1.19	1	1.41	**0.0449**
Lives with other smokers				
Sole smoker	1.26	1.06	1.49	**0.0077**
Other smokers in household	Ref.			
Social Environment				
Taxes				
High tax	1.60	1.29	2.00	**0.0000**
Moderate tax	1.18	0.99	1.39	*0.0595*
Low tax	Ref.			
100% Smoke-free Restaurants				
Restaurant ban	Ref.			
Not yet implemented	1.02	0.87	1.19	0.8103

Significant at the 5% level *Significant at the 25% level*

Table 4.3.4 Logistic Regression Predicting Successful Quit

	Predicting Quit Attempt (n=1181)			
Independent Variables	OR	Confidence limits		P-value
Smoking Behavior				
Baseline consumption				
< 10 CPD	1.17	0.81	1.69	0.4130
10-19 CPD	1.40	1.00	1.96	**0.0469**
20 + CPD	Ref.			
Baseline time to first cigarette				
> 30 mins	1.22	0.93	1.59	*0.1425*
Within first 30 mins	Ref.			
Timing of last quit attempt				
Made attempt within last 12 months	0.47	0.35	0.63	**0.0000**
Made attempt, > 12 months ago	0.88	0.63	1.25	0.4771
Never attempted to quit	Ref.			
Quitting Cognitions				
Quitting intention				
Plan to quit in next month	0.77	0.54	1.11	0.3960
Plan to quit in next 2-6 months	0.67	0.50	0.9	**0.0075**
No intention to quit	Ref.			
Interest in quitting				
High interest	1.50	0.99	2.26	*0.0526*
Moderate interest	1.14	0.79	1.64	0.4888
Low interest	Ref.			
Demographics				
Race/Ethnicity				
Hispanic	0.86	0.55	1.32	0.4757
Non-Hispanic White	Ref.			
Non-Hispanic Black	0.8	0.53	1.22	0.2998
Asian/Other	0.82	0.46	1.47	0.5070
Age				
18-29	Ref.			
30-49	0.95	0.69	1.3	0.7449
50-64	0.77	0.54	1.1	*0.1447*
65+	1.26	0.75	2.11	0.3729

Table 4.3.4 Logistic Regression Predicting Successful Quit

	Predicting Quit Attempt (n=1181)			
Independent Variables	OR	Confidence limits		P-value
Education				
Less than High school grad	Ref.			
High school grad	1.64	1.16	2.33	**0.0052**
Some college	3.16	2.21	4.52	**0.0000**
College grad	2.86	1.85	4.43	**0.0000**
Gender				
Male	1.23	0.97	1.55	*0.0809*
Female	Ref.			
Personal Environment				
Baseline home smoking ban				
No total ban	Ref.			
Total ban	1.67	1.31	2.12	**0.0000**
Lives with other smokers				
Sole smoker	1.34	1.05	1.71	**0.0198**
Other smokers in household	Ref.			
Social Environment				
Taxes				
High tax	1.07	0.74	1.55	0.7294
Moderate tax	0.98	0.74	1.29	0.8625
Low tax	Ref.			
100% Smoke-free Restaurants				
Restaurant ban	Ref.			
Not yet implemented	0.86	0.66	1.11	*0.2407*
Quitting-specific Personal variables				
Used pharma for quit				
No	Ref.			
Yes	0.4	0.31	0.53	**0.0000**
Social support for quit				
No	Ref.			
Yes	0.87	0.66	1.14	0.3091

Significant at the 5% level *Significant at the 25% level*

Table 4.3.5 Final Candidate variables for Cluster Analysis

Variable Group	SCT* Construct	Variable
Smoking Behavior	Behavior	Baseline consumption (CPD) Baseline dependence (time to first cigarette)
Timing of last quit attempt	Behavior	Timing of last quit attempt
Demographics	Personal	Race/Ethnicity Age Education Gender
Home Environment	Personal Environment	Baseline home smoking ban Lives with other smokers

*Social Cognitive Theory

4.4 DISCUSSION

The findings of this study support the hypothesis that quitting behavior outcomes, QA and 30D-A, are associated with a subset of personal, behavioral, and personal-environment variables identified in the evidence review. This suggests that despite changing patterns of smoking-related behaviors and social acceptance of smoking (Cummings and Proctor 2014), many of the variables associated with smoking cessation have not changed over the last decade. Variables from all categories from the conceptual model (personal, behavioral, and person environment categories) were significantly associated with QA, suggesting that factors from all three sources independently influence quitting behavior. Consistent with findings from the evidence review, smoking intensity (CPD) and timing of prior quit attempts were significant predictors of QA. Nicotine dependence (minutes to first cigarette) was not significant at the 5% level, but met the inclusion criteria for a candidate variable. The insignificance at the 5% level could be due to the use of the standard measure of dependence, having the first cigarette within 30 minutes of waking (Heatherton et al. 1991) being outdated. The measure may need to be revised to reflect changing behavior patterns that impact time to first cigarette. For example, the rise in the prevalence of smoke-free homes could have decreased the convenience of having a cigarette within 30 minutes of waking (IARC Working Group 2009) or the rise in the prevalence of smoke-free workplaces could mean people have a cigarette before work because they cannot have one when they arrive So, the variable may not be measuring only dependence. Further validation of this measure may be required as smoking patterns continue to change. The finding that smokers who reported a quit attempt in the 12 months prior to baseline were more likely to make a QA during the study period is consistent with the findings from other studies (Borland et al. 2011; Hyland et al. 2006; Partos et al. 2013). Although having a recent unsuccessful quit attempt is likely to reduce self-

efficacy to quit (Gwaltney et al. 2009), it may not reduce intention to do so and could lead to repeated failed attempts.

Consistent with previous studies, SFH was significantly associated with QA, suggesting that motivation to quit is higher in smokers that have implemented a smoke-free home (IARC Working Group 2009). Short term quit intention and high interest in quitting were independently associated with QA, suggesting that pro-quitting cognitions influence making an attempt (Curry, Grothaus, and McBride 1997; Pierce, Farkas, and Ilpin 1998; Rise et al. 2008) . The self-efficacy variable dropped out of the regression model because it did not reach the inclusion threshold of $p<0.25$. This may have been due to measurement problems because it was measured using a single-item variable (Bandura 2006) that was not administered to smokers who indicated no interest in quitting. This resulted in missing data and selection bias. In addition, the self-efficacy (SE) question was asked prior to the start of a quit attempt, which has been shown to be less predictive of cessation than measuring self-efficacy after the start of an attempt. That self-efficacy should be an important variable is suggested by the social cognitive theory (Bandura 1989) and has been shown to be associated with future smoking, albeit less robustly than expected, in meta-analysis (Gwaltney et al. 2009). All demographic variables reached the criteria for inclusion as cluster candidate variables.

Overall, the logistic regression model predicting QA indicated that many of the variables identified in the evidence review were independently associated with quit attempt, suggesting that there continues to be variation in personal, behavioral, and environmental factors that influence quit attempt.

The majority of variables associated with QA were also associated with 30D-A. The significant associations of personal and behavioral variables with 30D-A were generally

negative, with, medium term quit intentions and non-recent quit attempt all predicting lower odds of 30D-A. While personal characteristics suggesting low-dependence (e.g. low CPD and <30 day quit intention) were associated with increased odds of QA, none were significantly different to the reference group (20+ CPD, no intention to quit, and never tried to quit), with regards to 30D-A. The findings that smokers reporting moderate smoking intensity and those reporting 31 day to 6 month quit intention were more likely to report a 30D-A if they made an attempt than those reporting low CPD and 30 day quit intention could be due to light smokers not believing that their smoking behavior is a danger to their health (Schane, Ling, and Glantz 2010) and consequently not intending to quit imminently. Consistent with the health belief model, moderate smokers are more likely to have higher perceived susceptibility to smoking-related adverse health outcomes and perceive a greater threat from continuing to smoke (Janz and Becker 1984), which could translate into higher 30D-A rates. Also inconsistent with the QA model was the finding that, despite be more likely to make a quit attempt, smokers reporting an unsuccessful quit attempt in the 12 months prior to baseline are less likely to be successful if they attempt to quit. This could be due to reduced self-efficacy to quit (Gwaltney et al. 2009). According to relapse theory, maintaining high self-efficacy is key to preventing relapse (DiClemente CC et al. 1991; Larimer, Palmer, and Marlatt 1999; Niaura 2000; Niaura et al. 1988).

The personal environment variables, SFH and living with other smokers, was positively associated with 30D-A. Fewer demographic variables were significantly associated with the outcome measure 30D-A than QA, but all remained in the model as control variables. The finding that use of any FDA-approved pharmaceutical was significantly associated with 30D-A is likely to be due to self-selection of heavier smokers and those with lower belief in ability to quit being more likely to get help to quit, including using pharmaceutical aids

(Myers et al. 2015). Consequently, the finding of lower 30D-A in pharma-users is likely to be confounded by physiological and psychological predictors of 30D-A.

Overall, although the models were not parsimonious because variables with p-values between .05 and .25 were included, the model fit, tested using the Hosmer-Lemeshow test (Bursac et al. 2008), was good. The models identified a subset of nine variables for use in the cluster analysis.

The key limitation specific to the analyses in this chapter is the lack of a good self-efficacy variable. The importance of SE in future smoking is well established (Gwaltney et al. 2009) and the use of a multi-item measure that forces respondents to assess their self-efficacy in high-risk situations (Bandura 2006; Gwaltney et al. 2009) and is administered to all respondents would allow for a more robust assessment of the relationship between SE and quitting behavior. Limitations associated with cluster analysis discussed in Chapter 8.

4.5 CONCLUSION

This chapter aimed to use empirical analysis to reduce the size of the set of variables identified as candidate variables for cluster analysis by the evidence review, to a smaller set of variables that were independently associated with the outcome of interest: quit attempt and at least 30 days of abstinence at follow-up. This was successful and resulted in a set of nine candidate variables for use in cluster analysis (Chapter 5). The analysis also demonstrated that the majority of variables associated with quitting behaviors in previous studies continued to be associated with QA and 30D-A. However, the findings also suggest that some variables that were previously predictors of QA and 30D-A are no longer significantly associated with the outcome measures.

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CHAPTER FIVE

Identifying and Characterizing Cluster Groups

5.1 INTRODUCTION

5.1.1 Purpose of Analysis

The purpose of this analysis was to identify whether a cluster model can segment the whole smoking population into meaningful groups with respect to variables significantly associated with attempting to quit smoking (QA) and 30 day or longer abstinence (30D-A) at one year follow-up. Segmentation aims to identify subgroups of smokers that share common patterns of characteristics. These subgroups may share similar facilitators and barriers to cessation.

5.1.2 Clustering by Health Behavior Patterns

Cluster analysis is a technique used for classifying individuals within a population into groups that share similar characteristics including demographics, behavioral patterns, and personal living environment (Hofstetter et al. 2014). In the past it has been used in two distinct ways in the health behavior field: to identify commonly co-occurring health behaviors and to identify the commonly co-occurring characteristics of individuals that display an adverse health behavior. For example, a number of studies have used cluster analysis to segment a population by common patterns of smoking, diet, and physical exercise behavior (Conry et al. 2011; Schneider et al. 2009; de Vries et al. 2008). Others have focused on segmenting the overweight and obese population (Green et al. 2015; Kolodinsky and Reynolds 2009).The smoking population has also been segmented in prior studies. These studies are commonly driven by the Trans Theoretical Model (Norman et al. 2000; Smit, Hoving, and de Vries 2010), which is an intention-based model with little focus on environmental variables. A 2010 Cochrane review indicated that this model is an ineffective framework for improving intervention effectiveness (Cahill, Lancaster, and Green 2010). Other cluster analyses have been conducted in specific subgroups of the smoking population, such as post-partum women

(Simonelli and Velicer 2012) and occasional smokers (Edwards et al. 2010) and are not generalizable to the full adult population. A whole smoking population cluster analysis that incorporates personal, behavioral, and environment variables has not been reported in the literature.

In theory, differences between individuals with respect to the relatively small number of variables that predict smoking cessation are likely to occur in common patterns that result in different cessation outcomes. Using a nationally representative population dataset containing the majority of variables empirically associated with successful smoking cessation provides an opportunity to investigate whether these predictor variables cluster to form subgroups of individuals.

5.1.3 Utility of Clustering by Health Behavior Patterns

In order for segments identified by a cluster analytic approach to be useful for improving understanding of the smoking population, use in future research, and intervention design, they must exhibit between-cluster differences with respect to desired outcomes, for example, quit attempt or successful quit.

There has been research into a small number of subgroups of smokers with specified patterns of smoking-related characteristics, for example smokers who are unwilling or unable to quit (Costa et al. 2010; Emery et al. 2000) and *Low intensity smokers*, who consume fewer cigarettes than the majority of the smoking population. However, the characteristics of these groups are often study-specific and there is little consensus on the definition of each group (Costa et al. 2010; Schane, Ling, and Glantz 2010). That said, the findings of subgroup specific studies suggest that subgroups of smokers with different profiles of characteristics face different challenges when attempting to quit smoking (Levy, Romano, and Mumford 2005; Robertson et al. 2016). Identifying groups that have similar demographic, behavioral,

and personal environment patterns across the whole smoking population could help to identify new subgroups of smokers and commonly-faced patterns of behavior associated with different barriers and facilitators, This information could inform more broadly effective intervention design.

5.1.4 Hypotheses

This chapter aims to identify and test the validity of the optimal cluster model solution by evaluating the separation of cluster group with respect to the clustering variables. The cluster group variable should be significantly associated with each of the clustering variables and have face validity such that the group labels provide a very concise description of patterns of similarities and differences in the data (Everitt et al. 2011). Other relevant variables identified in the evidence review, including rejected candidate variables, should be associated with cluster group, but their exclusion from the cluster solution suggested they would not exhibit differences between every cluster group.

Hypothesis 1: All of the cluster groups identified will be significantly different to each other with respect to all of the clustering variables.

Hypothesis 2: Some, but not all, of the cluster groups identified will be significantly different to each other with respect to the variables excluded from the final cluster solution.

5.2 METHODS

5.2.1 Chapter-Specific Methods: Cluster Modeling Process

There are two key considerations when specifying a cluster model. Firstly, whether the clustering variables the most appropriate to yield a valid and cogent cluster solution. Secondly, given the variables selected for inclusion in the model, how many clusters are in the optimal cluster solutions that maximizes cohesion and separation and minimizes information loss (Everitt et al. 2011). These questions are answered for every iteration of the cluster model

using three key measures, until an optimum model is identified. The iterative process of identifying the best variable set and the optimum cluster number is outlined in Figure 5.2.1.

5.2.2.1 Measures Used In Cluster Modeling

Model selection was based on three measures, two of which identify the optimum number of clusters given the variables used, and one quantifies the importance of each variable used in a model. Details of the measures are in Box 5.1.

The selection of the initial set of candidate variables for the cluster analysis was identified in the evidence review and empirical analysis of individual variables and QA and 30D-A, described in Chapters 2 and 4 respectively. This set of variables was the starting point for the cluster modeling procedure.

Box 5.1 Cluster Modeling Measures

BIC Statistics

The **Bayesian information criterion (BIC)** (Schwarz 1978) evaluates the posterior probability of the competing models with specified priors and is commonly used in model selection (Everitt et al. 2011). This measure adjusts the log likelihood value for the number of parameters in the model in order to weight the model fit. Lower BIC values indicate a better the model (Vermunt and Magidson 2002).

The BIC equation is as follows: $BIC_{Mx} = 2 \times \log$ (maximized likelihood) − (no. of parameters) $\times \log(n)$ (Kass and Raftery 1995)

The **BIC Change** measures the information lost when cluster model $M_{(x+1)}$ is selected instead of cluster model M_x. It allows for comparison of the absolute information loss between two models.

$$\text{BIC Change} = BIC_{Mx} - BIC_{M(x+1)}$$

(continued)

Box 5.1 Cluster Modeling Measures (Continued)

The **Ratio of Distance Measure** is a ratio of the BIC change by moving from cluster model M_x to model $M_{(x+1)}$, where x is the number of clusters specified in the model. This measure allows for the evaluation of the relative information loss between two models.

$$\text{Ratio of Distance Measure} = \text{BIC Change}_{Mx} / \text{BIC Change}_{M(x+1)}$$

(Rousseeuw 1987; Tan, Steinbach, and Kumar 2005)

Selecting the final model for a given set of variables is a balance between the absolute information loss (BIC change) and the relative information loss (Ratio of Distance Measure). Reviewing a plot of BIC change by number of clusters allows visualization of the trade off (Figure 5.3.1). Where the gradient of the line becomes less steep, the additional information gained by having a higher number of parameters in the model is not balanced by the loss of cohesion and separation (measured by the silhouette coefficient).

Silhouette Coefficient

The **Silhouette Coefficient** evaluates cluster model fit and validity (Rousseeuw 1987). The measure is based on the comparison of the cohesion and separation of the cluster model, and essentially measures the proportion of the data points that fit well within a model compared to the proportion of data points effectively sitting between clusters (IBM SPSS Statistics Technote 2012). Higher values indicate a better model.

Predictor Importance

The **Predictor Importance Measure** is a measure of the relative contribution of each predictor in estimating the cluster model (Tan et al. 2005). Predictor importance indicates how well the variable can differentiate between clusters. The procedure is based on dominance analysis, which partitions the explained variance to evaluate the

(continued)

Box 5.1 Cluster Modeling Measures (Continued)

additional contribution of each predictor to the overall predictive ability of the model (Petscher, Schatschneider, and Compton 2013).

5.2.2.2 Identifying the Optimum Cluster Solution from the Initial Set of Candidate Variables

The SPSS two-step modeling procedure was automatically run using all nine of the candidate variables. The number of clusters generated was not fixed. A cluster model was run for each number of clusters from 1 to 8 and the models were ranked according to their relative information loss. The BIC table of statistics (Box 5.1) was examined and the model with the lowest loss of information (the highest ratio of distance measure) was selected. This resulted in identification of the optimum number of clusters given the clustering variables. The cluster procedure was then run, fixing the cluster number to that identified in the previous step and each respondent was assigned to a cluster group (Everitt et al. 2011). The cluster solution was also assigned a silhouette coefficient value to measure the cohesion and separation of the solution (Box 5.1). After optimization of the model, the importance of each variable was evaluated to determine whether the clustering procedure should be repeated with a smaller number of parameters in order to focus the model on the predictors that matter most. There is no consensus on the best cutoff value for predictor importance (Box 5.1). A liberal cutoff value of 0.1 was set to ensure that important variables were not incorrectly excluded. Because the predictor importance value is relative to the other variables in the model, the value can change for a given variable as a result of the set of variables included in the model. Consequently, a stepwise approach to variable removal was taken (Figure 5.2.1).

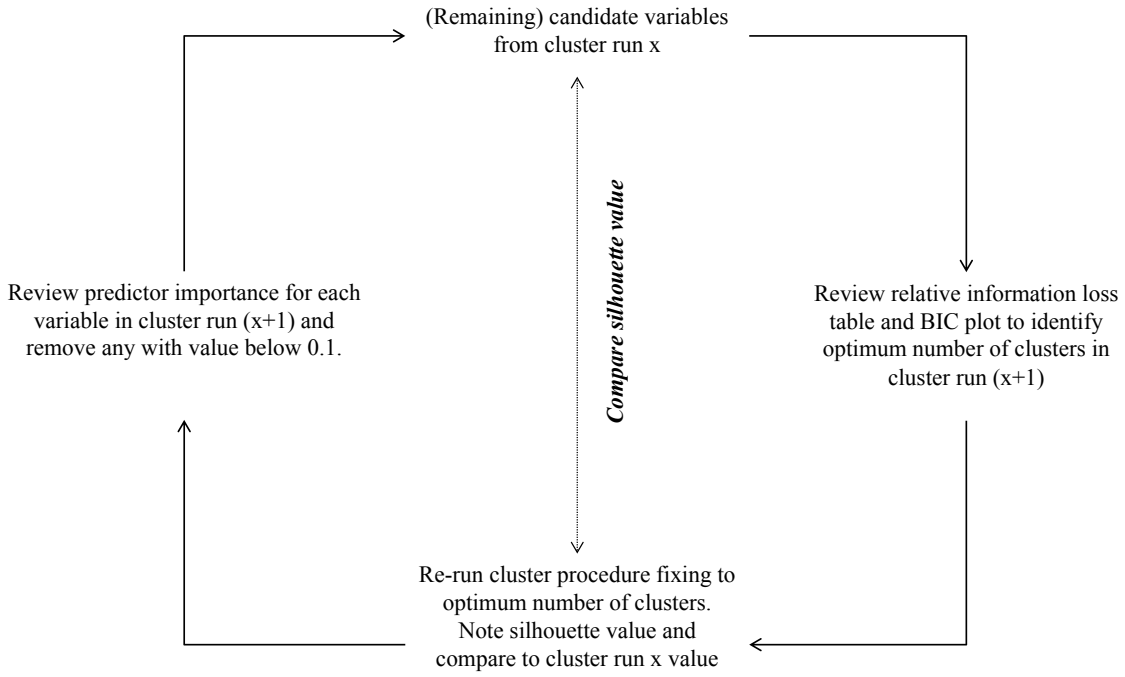

Figure 5.2.1 Iterative Cluster Procedure

5.3 RESULTS

5.3.1 Findings: Cluster Analysis Modeling

The results of the iterative cluster modeling process (Table 5.3.1) identified a five-cluster solution. The least efficient solution was generated with all nine candidate variables in a four-cluster solution (Table 5.3.1). This yielded an average silhouette coefficient value of 0.1, suggesting that the solution has low validity (Rousseeuw 1987). Analysis of the importance of the nine predictor variables included in the first run showed that two predictor variables, gender and household composition, had predictor importance values of less than 0.1, suggesting they are relative unimportant in estimating the model (Table 5.3.2). Consequently, these to variables were excluded from run 2. The second and third cluster runs yielded only small incremental improvements. Analysis of the importance of the remaining predictor variables resulted in 4 variables being selected for the fourth run (Tables 5.3.1 and 5.3.2). The fourth cluster run yielded a large improvement to the solution from the third run. This solution used the four remaining variables, baseline CPD, baseline dependence, baseline SFH, and R/E, to yield a five-cluster solution (Table 5.3.1). This also yielded an average silhouette coefficient value of 0.4, suggesting that the solution is of good validity (Everitt et al. 2011; Rousseeuw 1987; Tan et al. 2005).

Analysis of the importance of the four remaining predictor variables included in the fourth run showed that all variables had high predictor importance values, all over 0.85, suggesting that all four were important in estimating the model (Table 5.3.2). Consequently, this solution was defined as the optimal solution because it exhibited low redundancy in that it contained only variables important in estimating the model and it was of good quality, demonstrated by the silhouette (Rousseeuw 1987; Tan et al. 2005). Change in BIC against number of clusters for the final cluster run, Cluster Run 4 is shown in Figure 5.3.1. There are

two obvious changes in the gradient of the plot: one at a two-cluster solution and the other at a five-cluster solution (Figure 5.3.1). Although the two-cluster solution leads to a distinct change in the gradient of the slope, the decline in the BIC continues considerably until the five-cluster solution. This suggests that the five-cluster solution captures variation in the data that would be excluded if the two-cluster solution were selected. In addition, by having only two clusters, the discriminatory power of the solution is hugely reduced. Consequently, the five-cluster solution was selected.

5.3.2 Cluster Group Descriptions

The four clustering variables used in the final cluster analysis could be combined in 48 different permutations. Each of the 48 profiles was assigned to one of the five mutually exclusive cluster groups. Despite each cluster group containing more than one profile, the people within a cluster group should be similar to one another (cohesion), but significantly different to those in other cluster groups (separation) across all of the clustering variables. The cluster analysis resulted in all 2569 smokers in the study sample being assigned to one of 5 cluster groups, which differed by their combination of whether smokers had a baseline SFH, their baseline CPD, their dependence, and their R/E. The distribution of smokers between cluster groups is presented in Table 5.3.3. The largest cluster accounted for 27.2% of the sample, with the remaining 72.8% fairly evenly distributed between the other four clusters. As expected, there were highly significant differences between the clusters for each of the clustering variables across the Chi-Squared matrix (Table 5.3.3).

High dependence home smokers were the largest group and accounted for 27.2% of the smoking population (n=700). Smokers in this group all lived in a home where smoking was allowed in all or some places (Table 5.3.3). Over 70% (70.9%) smoked 20 or more

cigarettes per day. 100% reported high dependence. All smokers assigned to this group reported Non-Hispanic White race/ethnicity.

The *High dependence smokers with a SFH* group accounted for 17.8% of the smoking population (n=458). Smokers in this group were characterized by having a home smoking ban, but a moderate or heavy smoking intensity (Table 5.3.3). 100% of smokers assigned to this cluster had a SFH at baseline despite 100% reporting high dependence. Over 80% smoked 10 or more cigarettes per day. The group was predominantly comprised of Non-Hispanic White smokers (99.8%).

The *Low intensity smokers* group accounted for 17.4% of the smoking population (n=446) (Table 5.3.3). The majority of smokers in this group (62.4%) had a SFH at baseline. The most salient characteristic of the group was their light smoking intensity; 100% reported smoking less than 10 CPD. Nicotine dependence in this group was low, only 12.3% reported high dependence. All smokers assigned to this group reported Non-Hispanic White race/ethnicity.

The *Low dependence moderate-heavy smokers* group accounted for 19.0% of the smoking population (n=488). Over half of the smokers assigned to this group (51.0%) had a total home smoking ban at baseline (Table 5.3.3). The majority (62.4%) were moderate smokers (10-19 CPD), with the remainder being heavy smokers (20+ CPD). However, 100% reported low dependence (Table 5.3.3). All smokers assigned to this group reported Non-Hispanic White race/ethnicity.

The *Minority smokers* group accounted for 18.6% of the smoking population (n=477). Smokers in this group were less homogeneous than all of the other cluster groups (Table 5.3.3). Over half of the smokers assigned to this group (53.9%) had a 100% SFH and smoked less than ten CPD (54.1%). However, over 40% (45.5%) indicated high dependence. This

group accounted for almost all of the smoking population that were not of Non-Hispanic White race/ethnicity. 43.7% of the minority smokers identified as Non-Hispanic Black, 36.4% Hispanic, and 19.9% Asian and Other. None of this group reported Non-Hispanic White race/ethnicity (Table 5.3.3). This finding suggests that the patterns of smoking in minority R/E smokers are more varied than in the other clusters and the CPD, SFH, and dependence clustering variables do not demonstrate cohesion and separation in the same way in this group.

5.3.3 Naming the Cluster Groups

Two of the cluster groups, 2 and 3, were well differentiated by a single variable used to derive the cluster solution (Table 5.3.3). The salient feature of Group 2 (*Minority smokers*) was the race/ethnicity of the population, with all individuals assigned to this cluster being non-White (non-Hispanic). Group 3 (*Low intensity smokers*) was characterized by light smoking intensity. The other groups were differentiated by two variables. Group 4 (*Low dependence moderate-heavy smokers*) was differentiated by low nicotine dependence despite moderate to high levels of consumption. Groups 1 and 5 were differentiated by the combination of SFH and their high dependence (Table 5.3.3).

5.3.4 Post Hoc Analyses

Overall, post-hoc analysis indicated significant cohesion and separation between cluster groups and the different levels of all of the clustering variables (Table 5.3.4). Residual scores were calculated to assess the sources of variation in the Chi-Squared matrix (Table 5.3.4). Out of 55 cells in the four contingency tables (one table per clustering variable), six did not significantly contribute the variation in the matrix. These were: *Low dependence moderate-heavy smokers* x 20+ CPD, *High dependence home smokers* x 10-19 CPD, *Minority smokers* x SFH, and *Low dependence moderate-heavy smokers* x SFH. Only two clustering variables were included in the insignificant cells, CPD and SFH status (Table 5.3.4). This is

reflected in the more evident separation of cluster groups between the levels of the other two clustering variables, dependence and race/ethnicity (Table 5.3.3).

5.3.5 Characterizing the Cluster Groups by Non-Clustering Variables

The significance of the associations between the personal, behavioral, and environment variables identified as having a significant association with quit attempts and success in the evidence review, but not included in the final cluster solution, were tested using chi-squared tests. These significance tests showed that the cluster group was significantly related to all of the quit attempt/success-related variables (Table 5.3.5). *Post hoc* analysis identified which of the cells in the contingency matrices significantly contributed to the variation in the contingency table.

5.3.5.1 Characterizing the Cluster Groups by Demographic Variables

All three demographic variables excluded from the cluster analysis were significantly associated with cluster group in chi-squared analysis (Table 5.3.5). However, *post-hoc* analysis showed the cluster groups were not cleanly differentiated by these demographic variables. The majority of the variation in the X^2 matrix of cluster group vs. age was derived from the *Low intensity smokers* being significantly more likely to be aged 18-29 and significantly less likely to be aged 50-64, and *High dependence home smokers* being significantly more likely to be aged 50-64 and less likely to be aged 18-29 (Table 5.3.6). The variation was more evenly distributed through the X^2 matrix testing the association of cluster group vs. education level. The highest contribution to the variation was the association between *Minority smokers* and less than High School education level. *Low intensity smokers* were the most highly educated with lower proportions reporting a less than High School education level and higher proportions being significantly more likely to report being a college graduate. *Low dependence moderate-heavy smokers* were more likely to report both a less

than High School education or some college level of education (Table 5.3.6). Two trends emerged from the *post-hoc* analysis of gender and cluster group. Males were significantly more likely to in the *Minority smokers* cluster group, while females were significantly more likely to in the *Low intensity smokers* cluster group (Table 5.3.6).

5.3.5.2 Characterizing the cluster groups by quitting-related variables

Only a small number of cells in the contingency table were associated with prior quit attempts. The association between *Low intensity smokers* and having made a quit attempt in the 12 months prior to baseline was the greatest contributor to the variation in the matrix (Table 5.3.7). *Low intensity smokers* were also significantly less likely to have never tried to quit. *Heavy Smokers* were significantly more likely to have made an attempt more than 12 months ago and less likely to make an attempt in the last 12 months (Table 5.3.7). With respect to quitting cognitions, *Minority smokers* and *Low intensity smokers* were significantly more likely to intend to quit within the next month, while *High dependence home smokers* were significantly more likely to have no intention to quit. *High dependence smokers with a SFH* was significantly more likely to intend to quit in the next 2-6 months, but there was no significant relationship between this cluster group and quit intention within the next month (Table 5.3.7). *High dependence home smokers* were significantly less likely to have a one month quit intention and significantly more likely to have no intention to quit. *High dependence home smokers* accounted for the largest proportion of the variation in the chi-squared matrix of cluster group and quit interest. They were significantly more likely to report low interest and less likely to report high interest (Table 5.3.7). *Low intensity smokers* were significantly more likely to be highly interested in quitting. Less dependent heavy smokers were significantly more likely to be non-responders (Table 5.3.7). Low intensity smokers were significantly more likely to report high self-efficacy and significantly less likely to report

low self-efficacy and no interest in quitting. *High dependence home smokers* were significantly less likely to report high self-efficacy (Table 5.3.7b).

5.3.5.3 Characterizing the Cluster Groups by Smoking-related Environmental Variables

Minority smokers and *High dependence home smokers* accounted for all of the variation in the matrix of cluster group and household composition (Table 5.3.8). While *Minority smokers* were significantly more likely to live with other smokers, *High dependence home smokers* were significantly more likely to live with other smokers (Table 5.3.8). A large proportion of the variance in the chi-squared test of cluster group and smoke-free laws in state of residence resulted from the *High dependence home smokers* being significantly less likely to live in a state with 100% smoke-free restaurant laws (Table 5.3.8). The other significant finding was that *High dependence smokers with a SFH* and *Low intensity smokers* were more likely to live in in a state with 100% smoke-free restaurant laws (Table 5.3.8). Despite being significantly associated with cluster groups in standard chi-squared analysis (Table 5.3.5), after adjusting the significant p-value for multiple comparisons, only one pairwise comparison in the chi-squared matrix of cluster group and state-level tobacco taxation was statistically significant. This was that *Minority smokers* are significantly more likely to live in a moderate tax group state (Table 5.3.8).

Table 5.3.1. Cluster Run Results

# of Clusters	Cluster Run 1			Cluster Run 2			Cluster Run 3			Cluster Run 4		
	BIC	BIC Δ*	RDM*	BIC	BIC Δ*	RDM*	BIC	BIC Δ*	RDM*	BIC	BIC Δ*	RDM*
1	24150			38453.83			24150.61			18198.8		
2	20907	-3243.4	1.27	35662.14	-2791.7	1.62	20907.21	-	1.27	14648.1	-3550.7	1.53
3	18362	-2544.4	1.24	33982.58	-1679.6	1.1	18362.85	-	1.24	12355.4	-2292.7	1.14
4	16331	-2031.1	1.71	32465.75	-1516.8	1.56	16331.71	-	1.71	10349.3	-2006.1	1.36
5	15173	-1158	1.17	31536.74	-929	1	15173.78	-1158	1.17	8891	-1458.3	1.68
6	14197	-976.8	1.25	30608.40	-928.3	1.4	14197.02	-976.8	1.25	8042.5	-848.5	1.1
7	13429	-767.7	1.07	29981.60	-626.8	1.01	13429.30	-767.7	1.07	7277.6	-765	1.07
8	12714	-714.7	1.05	29363.88	-617.7	1.13	12714.56	-714.7	1.05	6564	-713.6	1.02
	silhouette = 0.1			*silhouette = 0.2*			*silhouette = 0.2*			*silhouette = 0.4*		

Shaded: Best Solution using specified variables

BIC Δ: Bayesian Information Criterion Change; RDM: Ratio of Distance Measure

Table 5.3.2. Cluster Run Predictor

Variable	Cluster Run 1	Cluster Run 2	Cluster Run 3	Cluster Run 4
Baseline consumption	1	1	1	1
Baseline time to first cigarette	1	0.88	1	1
Baseline prior quit attempts	1	0.11	0.04	x
Race/Ethnicity	1	0.4	1	1
Age	0.11	0.08	x	x
Education	0.27	0.09	x	x
Gender	0.02	x	x	x
Baseline home smoking ban	0.36	1	0.11	0.87
Household Composition	0.05	x	x	x

x Removed as a result of previous cluster runs

Table 5.3.3 Characterizing Cluster Groups by Clustering Variables

	Population			High dependence home smokers n=700(27.2%)		High dependence smokers with a SFH n=458(17.8%)		Low intensity smokers n=446(17.4%)		Low dependence moderate-heavy smokers n=488(19.0%)		Minority smokers n=477(18.6%)		
Variable	n	%	CI	%	CI	%	CI	%	CI	%	CI	%	CI	P value
Baseline Smoke-free home														
No total ban	1447	54.4	1.6	100	0.0			37.6	4	51.0	4.5	53.9	3.7	<.0001
Total ban	1122	45.6	1.6			100	0.0	62.4	4	49.0	4.5	46.1	3.7	
Baseline consumption														
< 10 CPD	768	31.8	1.6	0.0	0.0	18	3	100	0.0			54.1	3.5	<.0001
10-19 CPD	824	31.4	1.6	29.0	2.9	38.1	3.5			62.4	3.8	25.8	3.1	
20+ CPD	977	36.8	1.6	70.9	2.9	44.9	3.6			37.6	3.8	20.1	2.5	
Time to 1st cig														
≤ 30 min	1449	54.1	1.7	100	0.0	100	0.0	12.3	3		0.0	45.5	3.4	<.0001
> 30 min	1120	45.9	1.7					75.7	3	100	0.0	54.5	3.4	
Race/ethnicity														
Hispanic	138	8.9	1.1									30.7	3.8	
NH White*	2087	76.3	1.4	100	0.0	99.2	1.4	100	0.0	100	0.0			<.0001
NH Black*	220	10.2	1									45.0	3.2	
Asian/ Other	124	4.7	0.6			0.2	1.4					24.3	2.4	

*NH White = Non-Hispanic White; *NH Black = Non-Hispanic Black

Table 5.3.4 p-values for Adjusted Residual Post Hoc Test of Proportion: Cluster Group and Baseline Clustering Variables

Cluster Group	SFH		CPD			DEPENDENCE		RACE/ETHNICITY			
	Total Ban	No Total Ban	<10 CPD	10-19 CPD	20+ CPD	Within 30mins	> 30mins	Hispanic	Non-Hispanic	Non-Hispanic Black	Asian and Other
High dependence home smokers (n=700)	0.000	0.000	0.000	0.130	0.000	0.000	0.000	0.000	0.000	0.000	0.000
High dependence smokers with a SFH (n=458)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Low intensity smokers (n=446)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Low dependence moderate-heavy smokers (n=448)	0.270	0.270	0.000	0.000	0.690	0.000	0.000	0.000	0.000	0.000	0.000
Minority smokers (n=477)	0.760	0.760	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 5.3.5 Characterizing Cluster Groups by Baseline Non-Clustering Variables

	Population			High dependence home smokers n=700		High dependence smokers with a SFH n=458		Low intensity smokers n=446		Low dependence moderate-heavy smokers n=488		Minority smokers N=477		
Variable	n	%	CI	%	CI	%	CI	%	CI	%	CI	%	CI	P value
Demographics														
Age														
18-29	319	22.3	1.6	11.9	2.9	24.5	4.2	33.9	4.1	26.1	4.2	20.3	4.1	<.0001
30-49	1078	39.8	1.6	40.4	2.9	40.1	3.4	34.3	3.5	36.6	3.6	45.4	4.1	
50-64	917	29.6	1.2	37.6	2.8	28.9	2.8	22.2	2.7	29.5	3.2	27.1	2.6	
65+	255	8.3	0.7	10.2	1.7	6.5	1.4	9.7	1.9	7.8	1.5	7.2	1.4	
Education														
< H. S. grad	400	17.3	1.2	18.1	2.4	16.3	2.9	7.8	3.1	11.6	2.3	28.4	3.7	<.0001
H.S. grad	1034	39.4	1.5	44.5	2.8	42.2	3.7	34	4.3	39.5	3.8	35.4	3.6	
Some college	779	30.8	1.6	27.4	2.6	30.3	3.6	37.4	4.7	38.6	3.9	24.1	3.5	
College grad	356	12.5	1	9.9	1.7	11.2	2.1	20.8	2.8	10.4	2.1	12.1	2.3	
Gender														
Male	1202	53.8	1.5	54.1	3	57.8	3.3	46.1	3.7	48.3	3.4	60.3	3.1	<.0001
Female	1367	46.2	1.5	45.9	3	42.2	3.3	53.9	3.7	51.7	3.4	39.7	3.1	
Quitting Cognitions and Prior Quit Attempts														
Prior Quit Attempts														
Never tried to quit	903	37.4	1.6	36.3	3.2	38.2	4.0	28.5	3.6	41.8	3.9	40.5	3.6	<.0001
> 12 months ago	524	18.3	1.0	24.7	2.4	19.8	2.8	14.1	2.7	16.9	2.5	14.6	2.3	
Within last 12 mo.	1142	44.3	1.7	39.0	3.3	42.0	3.7	57.4	3.8	41.3	3.9	44.9	3.6	
Quitting intention														
Plan next month	400	16.5	1.3	8.3	1.6	12.9	2.2	24.7	3.4	13.4	3.2	24.6	3.6	<.0001
Plan next 2-6 month	606	22.8	1.4	21	2.5	29.9	3.7	26.3	3.3	21.4	3.3	18.3	2.7	
No intent to quit	1563	60.6	1.8	70.7	2.8	57.1	3.9	49	4	65.2	4.8	57	3.2	

Table 5.3.5 Characterizing Cluster Groups by Baseline Non-Clustering Variables

Variable	Population			High dependence home smokers n=700		High dependence smokers with a SFH n=458		Low intensity smokers n=446		Low dependence moderate-heavy smokers n=488		Minority smokers N=477		
	n	%	CI	%	CI	%	CI	%	CI	%	CI	%	CI	P value
Interest in quitting														
High interest	875	33.8	1.6	26.2	2.7	36.4	3.4	39.2	3.9	33.4	3.8	36.2	3.4	
Moderate interest	806	31.9	1.6	31.1	2.9	31.7	3.8	34.9	4	32.6	3.1	30.2	3.7	
Low interest	880	30.5	1.6	40.6	3.2	29.2	3.6	22.5	3.1	27.2	3.3	28.9	3.2	<.0001
Self-efficacy														
High	573	22.3	1.3	13.0	1.7	18.9	3.0	36.7	3.6	16.5	3.3	24.0	3.2	<.0001
Moderate	1158	45.6	1.7	45.3	3.2	50.9	4.0	41.3	3.8	50.9	4.0	40.9	4.2	
Low	184	6.8	0.8	11.7	2.2	5.2	1.5	2.5	1.7	6.8	1.7	5.8	1.6	
Not interested	654	25.3	1.4	30.0	2.9	25.1	3.5	19.6	3.0	25.8	3.1	24.0	3.2	
Personal Environment														
Household composition														
Sole smoker	1786	68.1	1.8	60.9	3.2	69.4	3.6	72.4	3.9	63.3	3.9	75.6	3.9	<.0001
Other smokers in HH	783	31.9	1.8	39.1	3.2	30.6	3.6	27.6	3.9	36.7	3.9	24.4	3.9	
Policy Environment														
Restaurants														
Smoke-free	1703	63.1	1.8	54.2	3.3	69.3	3.3	69.4	4.8	63.6	3.8	62.9	3.7	
Not Yet Implemented	866	36.9	1.8	45.8	3.3	30.7	3.3	30.6	4.8	36.4	3.8	37.1	3.7	<.0001
Taxes														
High tax	663	21.7	1.3	19.4	2.2	22.2	3.2	23.5	3.4	25.9	3.1	18.9	2.4	0.002
Moderate Tax	1098	47.7	1.9	45.4	3.0	44.8	4.1	51.3	4.8	43.0	3.6	53.4	3.5	
Low Tax	808	30.7	1.7	35.2	2.9	33.0	3.5	25.2	4.0	31.1	3.7	27.7	3.4	

Table 5.3.6 p-values for Adjusted Residual Post Hoc Test of Proportion: Cluster Group and Baseline Smoking-Related Demographic Variables

	AGE				EDUCATION				GENDER	
Cluster Group	18-29	30-49	50-64	65+	< H. S. grad	H.S. grad	Some college	College grad	Male	Female
High dependence home smokers	*0.00**	0.69	**0.00***	0.06	0.55	0.55	0.04	0.02	0.84	0.84
High dependence smokers with a SFH	0.19	0.84	0.76	0.11	0.55	0.16	0.76	0.37	0.06	0.06
Low intensity smokers	**0.00***	0.01	*0.00**	0.27	*0.00**	0.02	**0.00***	**0.00***	*0.00**	**0.00***
Low dependence moderate-heavy smokers	0.02	0.11	0.92	0.69	*0.00**	0.92	**0.00***	0.13	0.01	0.01
Minority smokers	0.19	**0.00***	0.11	0.32	**0.00***	0.02	*0.00**	0.69	**0.00***	*0.00**

* Significant after adjusting α for multiple comparisons; **bold is increase**; *italics is decrease*

Table 5.3.7a p-values for Adjusted Residual Post Hoc Test of Proportion: Cluster Group and Baseline Quitting-Related Variables

Cluster Group	PRIOR QUIT ATTEMPTS			QUIT INTENTION		
	<12 mo. Ago	>12 mo. Ago	Never tried	Within next month	Within next 2-6 months	No Intention
High dependence home smokers (n=700)	*0.00**	**0.00***	0.55	*0.00**	0.19	*0.00**
High dependence smokers with a SFH (n=458)	0.27	0.37	0.69	0.03	**0.00***	0.09
Low intensity smokers (n=446)	**0.00***	0.01	*0.00**	**0.00***	0.06	*0.00**
Low dependence moderate-heavy smokers (n=448)	0.13	0.42	0.03	0.05	0.37	0.02
Minority smokers (n=477)	0.76	0.01	0.07	**0.00***	*0.00**	0.04

* Significant after adjusting α for multiple comparisons; **bold is increase**; *italics is decrease*

Table 5.3.7b p-values for Adjusted Residual Post Hoc Test of Proportion: Cluster Group and Baseline Quitting-Related Variables

Cluster Group	QUIT INTEREST			SELF-EFFICACY			
	High Interest	Moderate Interest	Low Interest	High	Medium	Low	Not Interested in Quitting
High dependence home smokers (n=700)	0.00	0.62	**0.00***	*0.00**	*0.82*	**0.00***	0.02
High dependence smokers with a SFH (n=458)	0.23	0.92	0.55	0.37	0.26	0.27	0.69
Low intensity smokers (n=446)	0.01	0.16	*0.00**	**0.00***	0.31	*0.00**	*0.00**
Low dependence moderate-heavy smokers (n=448)	0.84	0.76	0.09	0.01	0.38	0.19	0.27
Minority smokers (n=477)	0.13	0.32	0.32	0.02	0.30	0.09	0.76

* Significant after adjusting α for multiple comparisons; **bold is increase**; *italics is decrease*

Table 5.3.8 p-values for Adjusted Residual Post Hoc Test of Proportion: Cluster Group and Baseline Smoking-Related Environmental Variables

Cluster Group	ONLY SMOKER AT HOME		STATE SF RESTAURANTS		STATE TOBACCO TAX		
	Only Smoker	Lives with Other Smokers	Smoke-free	Not 100% smoke-free	High Tax	Moderate Tax	Low Tax
High dependence home smokers (n=700)	*0.00**	**0.00***	*0.00**	**0.00***	0.13	0.16	0.01
High dependence smokers with a SFH (n=458)	0.55	0.55	**0.00***	*0.00**	0.76	0.19	0.27
Low intensity smokers (n=446)	0.04	0.04	**0.00***	*0.00**	0.32	0.11	0.01
Low dependence moderate-heavy smokers (n=448)	0.01	0.01	0.76	0.76	0.01	0.02	0.84
Minority smokers (n=477)	**0.00***	*0.00**	0.92	0.92	0.06	**0.00***	0.07

* Significant after adjusting α for multiple comparisons

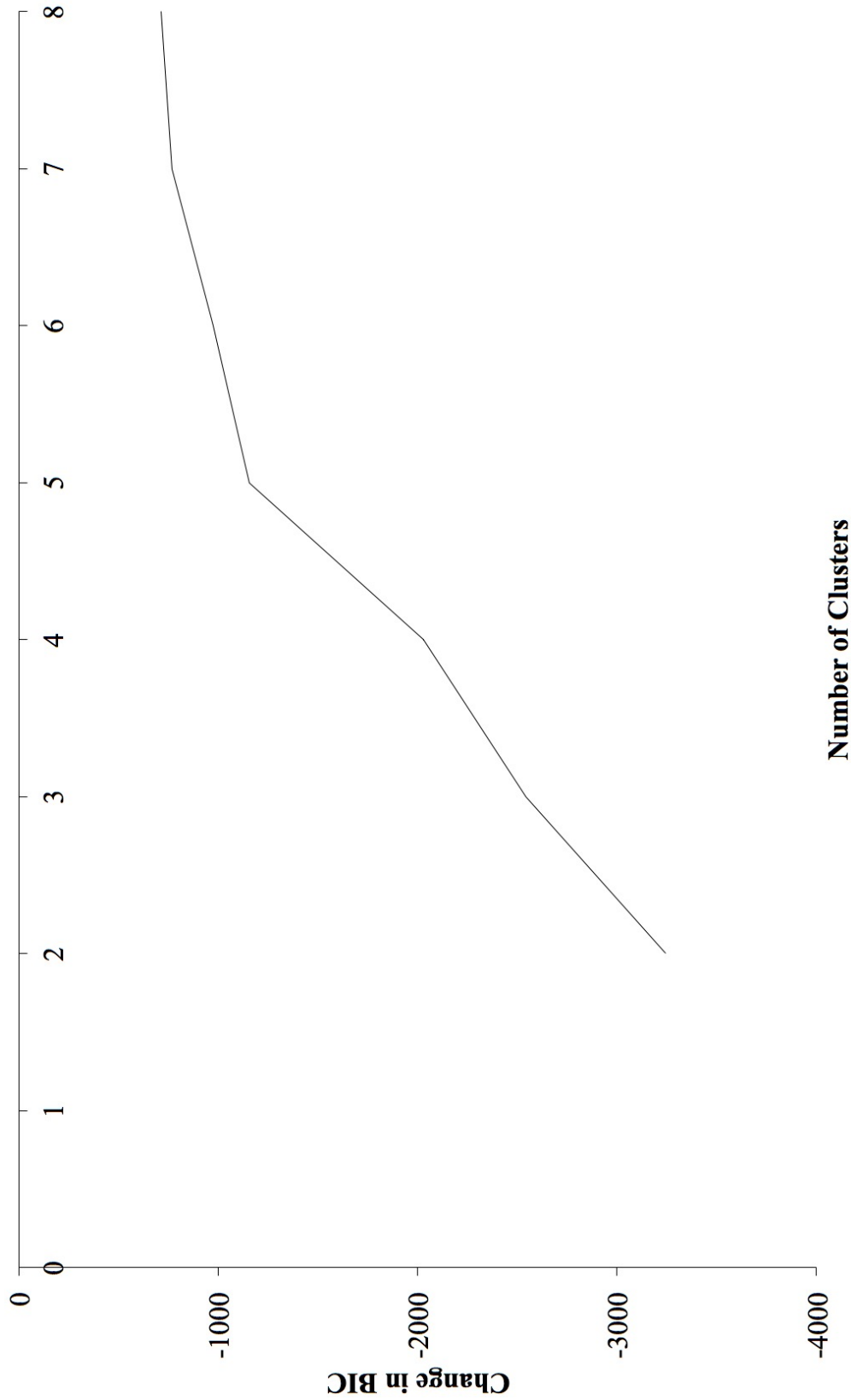

Figure 5.3.1. Cluster Run 4. Bayesian Information Criterion (BIC) Change by Number of Clusters

5.4 DISCUSSION

The findings of this study support the hypothesis that all of the cluster groups identified will be significantly different to each other with respect to all of the clustering variables. The inclusion of smoking intensity (CPD) and nicotine dependence in the cluster solution is unsurprising as these variables have long been associated with cessation (Emery et al. 2000; Pierce, Farkas, and Gilpin 1998). Smoke-free home has also been regarded as a strong predictor of quitting for many years (Farkas et al. 1999). The inclusion of race/ethnicity and the absence of all other demographic variables in the cluster solution is likely to reflect the different patterns of smoking and different attitudes towards smoke-free homes and smoking in minority-ethnic groups compared to Non-Hispanic White smokers (U.S. Department of Health and Human Services 1998). As part of the two-step cluster procedure, the characteristics of each respondent are examined and the respondent is assigned to new cluster or an existing cluster (Fraley and Raftery 1998). It is likely that during this first step of classification, the minority race/ethnicity groups were systematically different enough to the Non-Hispanic White smokers with respect to the clustering variables to be grouped into one "different smoking patterns" cluster. Examples of the differences in smoking behavior between Non-Hispanic White smokers and smokers from all other groups include: significantly lower smoking prevalence in Asian/Other and Hispanic groups (Agaku, King, and Dube 2014), especially in women, significantly higher proportions of the smoking population reporting intermittent and light smoking in Asian/Other and Hispanic groups (Trinidad et al. 2009), significantly lower proportions of the smoking population reporting heavy (20+ CPD) smoking in all minority groups (Trinidad et al. 2009), lower proportion of Non-Hispanic Black smokers with a smoke-free home, and higher proportion of Asian/Other with a smoke-free home (Cheng et al. 2015).

The exclusion of the prior quit attempts variable from the cluster solution is of interest, given the strong association with quitting outcomes in the regression analyses in Chapter 4 and the support for this association in the literature (Gilpin, Pierce, and Farkas 1997; Partos et al. 2013; Pierce et al. 1998). However, recall and reporting of previous quit attempts is notoriously inaccurate. Reasons previously suggested for this inaccuracy include smokers forgetting quit attempts that were short-lived and quit attempts that happened more than a two months prior to the survey (Berg et al. 2010; Gilpin and Pierce 1994). This could have led to systematic under-reporting of quit attempts in the responses to this question, which would reduce the variance in this variable, which could be responsible for it's exclusion.

As expected, *post hoc* analysis of the association between clustering variables and cluster group showed that all cells within each chi-squared matrix were significantly different to the expected value. As the aim of the cluster method is to maximize between-cluster differences, one measure of a robust cluster solution is separation between the clustering variables (Table 5.3.3). This finding indicated that the optimal cluster solution was robust and that each cluster group is distinct with respect to the clustering variables: baseline SFH, smoking intensity (CPD), nicotine dependence (time to first cigarette), and R/E. As hypothesized, the cluster group variable was associated with variables excluded from the cluster solution, but good separation between all of the clusters was not evident. This finding is expected because if the variables demonstrated good separation they would have been included in the final cluster solution.

Post hoc analysis showed that the two cluster groups not well characterized in the literature*, High dependence smokers with a SFH* and *Low dependence moderate-heavy smokers*, were associated with a number of smoking-related variables excluded from the final cluster solution. *, High dependence smokers with a SFH* were significantly more likely to

state an intention to quit in the next 2-6 months than *High dependence home smokers*, but equally likely to intend to make a quit attempt in the next month and report prior quit attempts as *High dependence home smokers*. Suggesting imminent quit intentions and past quit attempts may not have been the trigger for implementing the smoke-free in home prior to baseline. *High dependence smokers with a SFH* were also equally likely to be the only smoker in their household as *High dependence home smokers*, suggesting that implementing a smoke-free home may not have resulted from pressure from a nonsmoking partner to minimize exposure to secondhand smoke. The association with all other associated variables was similar, other than smoke-free restaurants (Table 5.3.5). Together, these findings suggest that the implementation of a smoke-free home could be the result of social diffusion of SFHs throughout the population (Borland et al. 2006). This hypothesis is supported by the finding that*, High dependence smokers with a SFH* were significantly more likely to live in a state with 100% smoke-free restaurant laws, which is consistent with previous findings that the strength of tobacco control is an important predictor of the prevalence of smoke-free homes in a state (Pierce, White, and Messer 2009) and that smoke-free laws are associated with quit intentions and attempts (Albers et al. 2007; Persoskie et al. 2015).

A large proportion of the variance in most *post hoc* test matrices came from three cluster groups: *Low intensity smokers, High dependence home smokers,* and *Minority smokers.* These findings were supported by with previous studies of heavy, light, and minority smokers (Emery et al. 2000; Ip et al. 2012; Lawrence et al. 2003; Nierkens et al. 2013; Schane, Glantz, and Ling 2009; Trinidad et al. 2009). For example, *High dependence home smokers* were significantly more likely to have last attempted to quit smoking more than 12 months ago, or never tried to quit and have a low interest in quitting (Darville and Hahn 2014; Ip et al. 2012), while *Low intensity smokers* were more likely to have tried within the last 12 months and have

a high interest in quitting (Levy, Biener, and Rigotti 2009). In addition, *Low intensity smokers* and *Low dependence moderate-heavy smokers* were more likely to intend quit in the next 30 days, consistent with the association between dependence and intention to quit (Hyland et al. 2006; Rise et al. 2008). Together these findings provide good face validity for the cluster solution.

5.5 CONCLUSION

This chapter aimed to use cluster analysis to identify whether the whole smoking population could be divided into meaningful subgroups, with respect to some or all of the variables previously identified as associated with attempting to quit smoking and abstinence. It also aimed to characterize the cluster groups identified with respect to other smoking-related variables and use these findings to test the face validity of the cluster groups. This exercise resulted in the successful identification of a five-cluster solution with good face validity. The five groups included two potentially new smoker subgroups and three groups synonymous with previously described subgroups.

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CHAPTER SIX

Cluster Groups as a Predictor of Quitting Behaviors

6.1 INTRODUCTION

6.1.1 Purpose of Analysis

The purpose of this analysis presented in this chapter is to evaluate whether the cluster groups identified in the previous chapter demonstrated predictive validity with respect to smoking cessation outcomes of interest: attempt to quit (QA) and successful 30 day or longer abstinence (30D-A) at follow up.

The combinations of smoke-free home (SFH), cigarettes per day (CPD), nicotine dependence, and race ethnicity groups that exhibited significant differences in the odds of QA and 30D-A were compared to identify potentially important differences in their profiles. This information could provide useful comparison groups for future research into subgroups in the smoking population and for identifying targets for intervention.

6.1.2 Importance of Predictive Validity of Cluster Groups

While it is important and efficient to use risk-based targeting of interventions in some scenarios, such as preventive care (Collins, Murphy, and Bierman 2004), it is not only those in high smoking prevalence groups who are at risk if they continue to smoke. All smokers are at risk if they continue to smoke and all stand to benefit from quitting smoking. Segmenting the whole smoking population using cluster analysis could result in the characterization of subgroups of smokers that exhibit combinations of personal, behavioral, and personal environment factors that have not been the focus of research and intervention in the past (King et al. 2008). However, to be useful in improving understanding of the smoking population and subsequently in intervention targeting, the cluster groups identified should exhibit characteristic differences that result in a differential likelihood of attempting to quit and achieving abstinence (Thompson and Higgins 2005). Current evidence suggests that a "one size fits all" approach is rarely the most effective method of improving health across a

population because most populations are heterogeneous and different subgroups often face different barriers to change (King et al. 2008). Given the interdependencies between personal factors associated with smoking cessation, the effectiveness of a population-level intervention could vary significantly between different subgroups. Thus, identifying cluster groups that have different odds of reporting quitting behaviors could assist in identifying the patterns of personal characteristics that maximize the likelihood of quitting, and the profiles of smokers who do not exhibit these characteristics.

6.1.3 Hypotheses

Hypothesis 1: The cluster group variable will be independently associated with QA and 30D-A in multivariate logistic regression analysis.

Hypothesis 2: The *Low intensity smokers* will be the most likely to make a QA and achieve 30D-A as they exhibit low CPD and have a SFH, both of which were strong predictors of QA and 30D-A in the previous chapter.

Hypothesis 3: *Heavy Smokers Without a SFH* will be less likely to make a QA and achieve 30D-A.

The clustering variables: baseline CPD, baseline nicotine dependence (measured as time to first cigarette), baseline smoke-free home, and race/ethnicity were removed from the modeling variables to prevent confounding with the cluster group variable in all analyses in this chapter. The cluster group variable was tested for confounding using the change-in-estimate criterion method, which indicated no confounding (Rothman, Greenland, and Lash 2008).

6.3 RESULTS

6.3.1 Findings: Univariate Analysis

In unadjusted analyses, cluster group was significantly associated with both quit attempt and success (Table 6.3.1 and Table 6.3.2 respectively).

High dependence home smokers were the least likely make a quit attempt during the study period (35%, +/- 3.2), while *Low intensity smokers* were the most likely to do so (60.3% +/- 4.1) (Table 6.3.1). *High dependence smokers with a SFH*, *Minority smokers*, and *Low dependence moderate-heavy smokers* had a similar likelihood of making a QA (46.0%, +/- 3.6, 46.8%, +/- 3.2, and 47.5%, +/- 3.2 respectively) (Table 6.3.1). Among smokers that reported a QA during the study period, *High dependence home smokers* were the least likely cluster group to report 30D-A (22.3%, +/- 3.2), while *Low intensity smokers* were the most likely to do so (35.9% +/- 4.2) (Table 6.3.2). *High dependence smokers with a SFH*, Minority *smokers*, and *Low dependence moderate-heavy smokers* all reported intermediate likelihoods of 30D-A (26.9%, +/- 5.4, 28.3%, +/- 4.3, and 32.2%, +/- 5.8 respectively) (Table 6.3.2). The confidence intervals were larger when testing the associations between cluster group and 30D-A than between cluster group and QA. This could reflect the smaller sample size for the 30D-A tests or could reflect under-reporting of quit attempt, which was discussed in Chapter 4 (Tables 6.3.1 and 6.3.2). Univariate analysis for other independent in the regression models is detailed in Chapter 4 in Tables 4.3.1 and 4.3.2.

6.3.2 Findings: Multivariate Analysis

6.3.2.1 Association Between Cluster Group and Quitting Behaviors (QA and 30D-A)

In adjusted analyses, all cluster groups were significantly more likely to make a quit attempt in the study period than *High dependence home smokers*. *Low intensity smokers* were most likely to report an attempt (AOR 1.84; 95% C.I. 1.45, 2.33; $p<0.0001$) (Table 6.3.1).

High dependence smokers with a SFH, *Minority smokers*, and *Low dependence moderate-heavy smokers* were all less likely to make an attempt than the *Low intensity smokers,* but more likely than *High dependence home smokers* (AOR 1.26; 95% C.I. 1.01, 1.58; p=0.044, AOR 1.21; 95% C.I. 1.00, 1.47; p=0.049, and AOR 1.34; 95% C.I. 1.07, 1.68; p=0.01, respectively) (Table 6.3.1).

Low intensity smokers and *Low dependence moderate-heavy smokers,* were significantly more likely to report 30D-A than *High dependence home smokers* (AOR 1.55; 95% C.I. 1.10, 2.18; p=0.011, and AOR 1.49; 95% C.I. 1.03, 2.15; p=0.035, respectively) (Table 6.3.2). However, despite being more likely to make an attempt, two cluster groups, the *High dependence smokers with a SFH* and *Minority smokers,* were equally likely to report 30D-A as the *High dependence home smokers* (p=0.368 and p=0.394 respectively) (Table 6.3.2).

6.3.2.2 Comparing Cluster Group Characteristics and Odds of QA and 30D-A

The *High dependence smokers with a SFH* and *High dependence home smokers* share many characteristics. The main difference between these two groups is the SFH (Table 6.3.3). While the *High dependence smokers with a SFH* were more likely to make a QA, they were no more likely to be successful despite having a SFH (Tables 6.3.2 and 6.3.3). The *Low intensity smokers,* who were most likely to make a quit attempt and report 30D-A, were also most likely to have characteristics associated with smoking cessation, namely low dependence, low CPD, and a SFH (Table 6.3.3). The *Low dependence moderate-heavy smokers* were the only other group with significantly higher odds of 30D-A than the *High dependence home smokers.* The shared characteristic of the *Low intensity smokers* and *Low dependence moderate-heavy smokers* is low dependence, with the *Low dependence moderate-heavy smokers* having

a higher CPD and lower SFH prevalence than *Low intensity smokers* (Table 6.3.3). The *Minority smokers* were a heterogeneous group with respect to the clustering variables, making comparison of their characteristics with other groups difficult (Table 6.3.3).

Table 6.3.1 Logistic Regression Predicting Quit Attempt

	Sample		QA		Predicting Quit Attempt (n=2569)			
Independent Variables[$]	n	%	%	CI	OR	Confidence limits		P-value
*Cluster Group***								
High dependence home smokers	700	27	36.0	3.2	Ref.			
High Dependence Smoker with SFH	458	18	46.0	3.6	1.26	1.01	1.58	0.044
Low intensity smokers	446	17	60.3	4.1	1.84	1.45	2.33	<0.0001
Low dependence moderate-heavy smokers	488	19	47.5	3.6	1.34	1.07	1.68	0.010
Minority smokers	477	19	46.8	3.2	1.21	1	1.47	0.049
*Timing of Prior Quit Attempts****								
Within last 12 months	1142	44	63.1	2.6	2.09	1.73	2.53	<0.0001
> 12 months ago	524	20	34.5	3.2	1.09	0.89	1.33	0.396
Never attempted to quit	903	35	31.1	2.5	Ref.			
*Quitting intention****								
Plan in next month	400	16	72.2	4.1	1.78	1.39	2.29	<0.0001
Plan in next 2-6 months	606	24	56.8	3.8	1.18	0.96	1.46	0.108
No intention to quit	1563	61	36.9	1.9	Ref.			
*Interest in quitting****								
High interest	875	34	65.0	3.2	2.16	1.72	2.72	<0.0001
Moderate interest	806	31	42.0	2.7	1.11	0.92	1.35	0.277
Low interest	888	35	32.2	3.8	Ref.			
*Household composition***								
Sole smoker	1786	70	48.1	1.9	1.27	1.08	1.51	0.005
Other smokers in household	783	30	42.3	3.2	Ref.			

Controlling for: Age, Education, Gender, Tobacco Taxes, and Smoke-free Restaurants.

[$] Univariate Association with Successful Quit (* <.05 ** <.01 *** <.001)
Details in Chapter 4 and Table 4.3.1.

Table 6.3.2 Logistic Regression Predicting 30+ Day Abstinence (30D-A)

	Sample		30D-A		Predicting 30D-A (n=1181)			
Independent Variables[$]	n	%	%	CI	OR	Confidence limits		P-value
*Cluster Group******								
High dependence home smokers	242	20%	22.3	4.6	Ref.			
High Dependence Smoker with SFH	206	17%	26.9	5.4	1.18	0.82	1.7	**0.368**
Low intensity smokers	272	23%	35.9	4.2	1.55	1.1	2.18	**0.011**
Low dependence moderate-heavy smokers	225	19%	32.2	5.8	1.49	1.03	2.15	**0.035**
Minority smokers	236	20%	28.3	4.3	1.18	0.81	1.72	**0.394**
*Timing of Prior Quit Attempts****								
Within last 12 months	720	61%	24.2	2.8	0.49	0.36	0.65	**<0.0001**
> 12 months ago	177	15%	35.7	5.8	0.91	0.65	1.26	**0.550**
Never attempted to quit	284	24%	34.0	4.5	Ref.			
*Quitting intention***								
Plan in next month	337	29%	23.1	4.0	0.68	0.51	0.91	**0.009**
Plan in next 2-6 months	288	24%	27.3	5.0	0.78	0.55	1.11	**0.166**
No intention to quit	556	47%	31.0	3.0	Ref.			
*Interest in quitting****								
High interest	573	49%	25.3	3.7	1.65	1.1	2.47	**0.015**
Moderate interest	335	28%	31.1	4.4	1.18	0.82	1.69	**0.378**
Low interest	273	23%	29.3	5.2	Ref.			
*Household composition**								
Sole smoker	854	72%	29.2	2.4	1.34	1.05	1.72	**0.019**
Other smokers in household	327	28%	24.0	4.1	Ref.			

Controlling for: Age, Education, Gender, and Pharma Use During Quit Attempt, Tobacco Taxes, and Smoke-free Restaurants.

[$] Univariate Association with Successful Quit * <.05 ** <.01 ***<.001
Detailed in Chapter 4 and Table 4.3.2.

Table 6.3.3 Cluster Group Characteristics (Abridged from Chapter 5; for statistical analysis see Table 5.3.3)

	High dependence home smokers	High Dependence smokers with a SFH	Low intensity smokers	Low dependence moderate-heavy smokers	Minority smokers
Independent Variables	% of cluster group	% of cluster group	% of cluster group	% of cluster group	% of cluster group
Smoking Behavior					
Baseline consumption					
< 10 CPD	0.0	18.0	100		54.1
10-19 CPD	29.1	38.1		62.4	25.8
20+ CPD	70.9	44.8		37.6	20.1
Baseline time to first cigarette					
Within 30 min	100	100	12.3		45.5
> 30 min			87.7	100	54.5
Home Environment					
Baseline SFH					
Total ban		100	62.4	43.4	46.1
No ban	100		37.6	56.6	53.9
Race/Ethnicity					
Hispanic					37.4
Non-Hispanic White	100	100	100	100	
Non-Hispanic Black					42.9
Asian and Other					19.7

6.4 DISCUSSION

The findings of this study support the hypothesis that the cluster group variable would be independently associated with QA and 30D-A in multivariate regression analysis. Consistent with the literature, *High dependence home smokers* were the least likely to attempt to quit (Cohen, McDonald, and Selby 2012; Costa et al. 2010; Hughes 2011; Levy, Romano, and Mumford 2005; Vangeli et al. 2011) and the *Low intensity smokers* the most likely. This is likely to reflect the profile of characteristics of these two groups. *Low intensity smokers* reported low dependence, low CPD, and relatively high SFH prevalence at baseline, all of which are associated with increased odds of QA (Vangeli et al. 2011). At the other end of the spectrum, *High dependence home smokers* reported high dependence, high CPD, and no SFH at baseline, characteristics associated with lower odds of QA (Vangeli et al. 2011). All cluster groups were more likely to make a QA than *High dependence home smokers*, suggesting that any difference in smoking behavior and personal environment was associated with an increase in the likelihood of making a quit attempt. This is consistent with triadic determinism (Bandura 1986), which posits that a change in a single behavior or environmental factor acts through psychological mechanisms (Bandura 1999) to influence behaviors and environmental factors. This could be due to smokers with any of the characteristics associated with QA being more aware that smoking is a problem (Janz and Becker 1984; Kruger et al. 2016) through higher perceived threat and knowledge of harms (Hopkins et al. 2001). These cognitive differences may have led to smokers making changes to their behavior or environment, which the *High dependence home smokers* have not made.

The finding that *Low intensity smokers* and *Low dependence moderate-heavy smokers*, who both had high proportions of their members reporting low dependence, is expected as dependence is an important determinant of 30D-A (Vangeli et al. 2011). Although this is

consistent with previous studies (Vangeli et al. 2011), high smoking intensity is often used as a surrogate marker for nicotine dependence (Baker et al. 2007; Heatherton et al. 1991), so the finding that some smokers maintain a reasonably high intensity without becoming dependent is of interest. Further research investigating how the *Low dependence moderate-heavy smokers* maintain dependency low, why they continue to smoke moderately or heavily in the absence of high dependence when it is becoming less and less socially acceptable (Bayer and Stuber 2006; Rennen et al. 2014), and more expensive (Chaloupka, Levy, and Huang 2011; Chaloupka, Yurekli, and Fong 2012; Kozlowski 2015) could identify new targets for intervention in this group. The significantly higher odds of 30D-A in the *Low dependence moderate-heavy smokers* supports the claims of low dependence and suggests the self-report nature of the dependence data is unlikely to have led to erroneous reports of dependency. It is possible that the measure of dependency, smoking the first cigarette of the day within 30 minutes of waking, is actually measuring one or more latent variables that impact a smokers' ability to smoke within the first 30 minutes of waking in addition to the physiological drive to alleviate discomfort from reduced blood plasma levels of nicotine (Heatherton et al. 1991). For example, other responsibilities they have in the first 30 minutes after waking such as caring for children, ease of getting outside to smoke, and an acceptable place to stand and smoke outside.

The result that *High dependence smokers with a SFH* were equally likely to report 30D-A as the *High dependence home smokers* was somewhat unexpected because SFH has been shown to be significantly associated with an increase in cessation rates in those who make a quit attempt in a mixed dependence smoker population (Hyland et al. 2009). It suggests that changes to the home environment alone may not be sufficient for many smokers to influence changes in behaviors that lead to 30D-A in those who make an attempt to quit.

However, having identified these distinct groups could enable future researchers to employ qualitative and quantitative research to understand why the *High dependence smokers with a SFH* implemented this restriction and how they have adapted their behavior to continue to smoke at relatively high intensity.

Finally, the finding that *Minority smokers* were no more likely to report 30D-A if they made an attempt than *High dependence smokers with a SFH* and *High dependence home smokers* is of interest because overall this group are less dependent and have lower smoking intensity than *Low dependence moderate-heavy smokers.* This could be due to the impact of the Reverters, in which minority R/E groups were over-represented (discussed in Chapter 3, Section 3.2). It could also be the result of different smoking patterns and styles in some minority groups that result in higher dependence from relatively low consumption (Apelberg et al. 2012; Benowitz et al. 2011; Okuyemi et al. 2007). Another possibility is the different race/ethnicity groups being grouped together. Although the *Minority smokers* cluster group exhibits good separation from the other groups, it does not have good cohesion because it is very heterogeneous with respect to the clustering variables. There are 34 combinations of clustering variables represented in this group (mean frequency of 6% of population; largest group only 10% of the population; therefore no combination dominates). Consequently, it is difficult to draw any conclusions about this cluster group without elucidating the impact of the individual R/E groups. Variation in smoking behaviors between minority R/E groups is consistent with previous research that indicates smokers from minority populations have very different patterns of smoking compared to other minority R/E groups and Non-Hispanic White smokers (Hopkins et al. 2001; Siahpush et al. 2010; U.S. Department of Health and Human Services 1998). For example, Hispanic and Asian American smokers are more likely to have SFH than Non-Hispanic White smokers, while African American smokers are less likely

(Gilpin et al. 1999; Hopkins et al. 2001; Mills et al. 2009). Overall individual race/ethnicity groups within *Minority smokers* are too different to be grouped together and further research, with a larger sample size of minority smokers than is available in the TUS-CPS, is required to understand the influences of the clustering variables within Minority populations.

The insights provided by comparing the characteristics of cluster groups with different odds of QA and 30D-A indicated that smokers with different profiles of cluster variable characteristics could have different intervention needs when quitting smoking. Although translation of these findings into practice would require further research, the results could help to prioritize targets for intervention in different subgroups of smokers and help to avoid potential diversion and dilution effects that can occur when interventions target many factors simultaneously without considering the many possible interactions between them (Kraemer et al. 2001).

One possible limitation of this study is the length of time between baseline and follow-up. Two cluster groups, *Minority smokers* and *High dependence home smokers* could have been significantly more likely to achieve 30D-A in a longer study, especially if social diffusion is slow in one or both of these groups. In general, changing social norms is known to be a slow process (Zhang, Cowling, and Tang 2010). A further limitation is that identifying cluster groups that have higher odds of quitting relative to one another does not acknowledge the fact that, in absolute terms, all cluster groups have low cessation rates. While there is a potential benefit to encouraging changes in behavior that lead to smokers having characteristics that increase the likelihood of abstinence, this is unlikely to result in rapid increases in the smoking cessation rate. It is more likely to accelerate the pace of change in smoking behaviors such as lowering average CPD and increasing SFH prevalence.

6.5 CONCLUSION

The findings presented in this chapter indicate that all other cluster groups were more likely to make a quit attempt than the *High dependence home smokers*. However, only cluster groups with a high proportion of members reporting low dependence, the *Low intensity smokers* and the *Low dependence moderate-heavy smokers*, were more likely to report 30D-A at follow-up. The finding that *High dependence smokers with a SFH* and *High dependence home smokers* were equally likely to report 30D-A suggests that further research is needed into the association between having a SFH and 30D-A in high dependence, moderate to heavy smokers who make an attempt to quit.

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CHAPTER SEVEN

Association of Cluster groups of Smoke-free Home Implementation and Lower Consumption

7.1 INTRODUCTION

7.1.1 Purpose of Analysis

The purpose of the analysis presented in this chapter is to test the utility of the clusters groups in identifying different trajectories of change in the two smoking-related behaviors that are changing across the whole smoking population: living in a smoke-free home (SFH) (King et al. 2016) and reducing consumption to less than 10 cigarettes per day (CPD) (Pierce et al. 2011).

7.1.2 Smoke-free Homes as a Predictor of Smoking Behavior and Cessation

Smoke-free home implementation has long been associated with an increased probability of making a quit attempt (Mills et al. 2009; Yong et al. 2014) and with lessened relapse among individuals who make a quit attempt (Vijayaraghavan et al. 2013). In 2009, a review by Mills *et al* concluded that "there is strong and consistent population-level evidence that a smoke-free home is associated with increased smoking cessation and decreased cigarette consumption in adult smokers." Although evidence for the direct impact of SFH on smoking cessation is not voluminous because it is not frequently included in data collection (IARC Working Group 2009), studies report that smokers who implement a SFH are more likely to be motivated to make a quit attempt (Farkas et al. 1996; Pierce, Farkas, and Gilpin 1998; Shields 2007). It has also been suggested that implementing a SFH will provide physical barriers to smoking that could increase the chances of cessation (Mills et al. 2009). In turn this leads to reduced consumption, and increased self-efficacy to quit, all of which improve the likelihood of making a successful quit attempt (Berg et al. 2006; Shields 2007).

7.1.3 Which Smoker Characteristics Are Associated with Having a Smoke-free Home

Numerous personal factors have been associated with having a smoke-free home (SFH) (Gilpin et al. 1999; King, Patel, and Babb 2014). Many of these are demographic. For

example, Hispanic and Asian American smokers are more likely to have a SFH than Non-Hispanic White smokers, while Non-Hispanic Black smokers are less likely (Gilpin et al. 1999; Hopkins et al. 2001; Mills et al. 2009). Male smokers, those with a higher education level, and younger smokers are also more likely to have a smoke-free home (Gilpin et al. 1999; Mills et al. 2009) In addition, having a SFH is associated with awareness of the harms of secondhand smoke (SHS) (Pizacani et al. 2003). In terms of behavioral factors associated with having a SFH, there is a consistently reported association between low cigarette consumption and SFH (Gilpin et al. 1999; Mills et al. 2009). Lastly, the personal environment factors of living with no other smokers and living with children have also been associated with SFH (Kairouz et al. 2015; Mills et al. 2011; Pizacani et al. 2003).

7.1.4 Smoking Intensity as a Predictor of Smoking Behavior and Cessation

There is strong evidence for the association between smoking fewer cigarettes per day (CPD), an increased chance of making a quit attempt (Vangeli et al. 2011), and successfully abstaining from smoking (Vangeli et al. 2011), with fewer cigarettes predicting more favorable cessation outcomes (Heatherton et al. 1991; Levy, Romano, and Mumford 2005). In addition, CPD was a significant predictor of QA and 30D-A in the analyses presented in chapter 4, Tables 4.3.3 and 4.3.4, respectively. Although the effectiveness of reducing CPD prior to making a quit attempt in improving cessation outcomes is conflicted (Cheong, Yong, and Borland 2007; Farkas 1999; Farkas et al. 1996), reducing consumption is a common behavior in smokers who intend to make a quit attempt (Cheong et al. 2007) and in those who relapse, who often take considerable time to return to their previous smoking intensity after a failed QA and may never do so (Morchon, Masuet, and Ramon 2007). CPD reduction also increases the probability of future cessation in those not currently interested in quitting,

suggesting that reducing smoking intensity can be a step towards cessation independent of intention to quit (Hughes and Carpenter 2006).

7.1.5 Which Smoker Characteristics Are Associated With Low Smoking Intensity

Smoking less than 10 CPD is associated with many of the same factors as living in a smoke-free home. For example, Non-Hispanic Black, Hispanic, and Asian American/Other smokers are more likely to be Low intensity smokers than Non-Hispanic White smokers (Trinidad et al. 2009; Zhu et al. 2007). Female smokers, those with a higher education level, and younger smokers are also more likely to be Low intensity smokers (Levy, Biener, and Rigotti 2009). Environmental and social factors associated with light smoking include having less than 50% of friends being smokers, having a smoke-free workplace, and having a smoke-free home (Levy et al. 2009).

7.1.6 Association of Cluster group with Smoke-free Home Implementation and with Reduced Smoking Intensity

As previously discussed, rates of SFH implementation and CPD reduction are rising across the whole smoking population as a result of social diffusion. Concurrently, smoke-free laws and negative attitudes to smoking are becoming more prevalent (Borland et al. 2006; Gilpin, Lee, and Pierce 2004).

Given the baseline rates of SFH and low CPD differ significantly between cluster groups and the association of cluster group with quitting behavior, it would be expected that the rate of SFH implementation and reduction of smoking intensity to <10 CPD would differ between the cluster groups. The *Low intensity smokers, Low dependence moderate-heavy smokers, and Minority smokers,* would appear more likely to implement a SFH than the *High dependence home smokers* because they exhibit characteristics associated with a SFH, namely light smoking intensity and minority race/ethnicity status. The *High dependence smokers with*

a SFH and *Minority smokers* would appear more likely to reduce CPD to less than 10 than the *High dependence home smokers* because having a SFH is strong associated with low CPD. However, because these groups have higher rates of SFH and low CPD at baseline, smokers who are going to make adaptive changes may have already done so. This could result in other cluster groups having higher rates of implementation of SFH and reduction of CPD than would be predicted by the theory of reciprocal determinism (Bandura 1978).

Identifying which groups are less likely to implement a SFH and reduce CPD to <10 could be helpful in finding new interdependencies between the clustering variables and provide insights into trajectories of change, potentially identifying targets for intervention that focus on these intermediate outcomes to cessation. Although the overall goal of tobacco control is cessation, in some smokers it may be necessary to approach long term goals with stepwise proximal goals, such as changes to smoking behavior and personal environment, in order to improve their chances of quitting smoking in the future.

7.1.7 Hypotheses

Hypothesis 1: In the sub-population of smokers that does not have a SFH at baseline, some cluster groups will be more likely to implement a SFH than others.

Hypothesis 2: In the sub-population of smokers that smoke more than 10 CPD at baseline, some cluster groups will be more likely to reduce their CPD to less than 10.

7.2 CHAPTER SPECIFIC METHODS

7.2.1 Smoke-free Home Implementation

7.2.2.1 Study Population and Data

The outcome measure for this analysis was implementation of a SFH. Consequently, smokers that stated that “no one is allowed to smoke anywhere inside your home” at baseline were excluded from the sample because they already had a SFH at baseline. 1447 of the 2569

smokers in the total study sample met this inclusion criterion. Once a 100% SFH is implemented, it is unlikely to be removed. Of the four cluster groups with members that reported a SFH at baseline the population weighted mean SFH at follow-up was 83% and the range 79%-89% (data not shown). Due to the SFH variable being one of the clustering variables, one cluster group, *High dependence smokers with a SFH*, was excluded from the analysis due to 100% of members reporting a baseline SFH.

Of the 1447 smokers that met the aforementioned inclusion criteria, 1377 responded "smoking is allowed in some places or at some times inside your home" or "smoking is permitted anywhere inside your home" to the home smoking question at baseline. A response for this data item was missing for the remaining 70 respondents. Because SFH was the outcome variable in the analysis, these 70 respondents were excluded from both univariate and multivariate analysis.

7.2.2.1 Selection of Covariates for Logistic Regression Modeling

Univariate analysis was undertaken to identify covariates for use in multivariate logistic regression modeling that aimed to evaluate the relationships between: 1. Cluster group and implementation of a smoke-free home, and 2. Cluster group and reduction of CPD to less than 10 per day. Chi-squared tests were used to test the significance of association of each independent variable with the outcome measure. A p-value of 0.25 was selected as the "F-to-Enter" value (Bendel and Afifi 1977), which is used in variable selection in stepwise regression. This value was chosen because using a more conservative value, such as 0.05, can lead to the exclusion of variables known to be important (Bursac et al. 2008).

All demographic variables were selected as covariates irrespective of the results of the Chi-squared tests, because not only are they the traditional groupings used in epidemiological

and public health research and practice, they also reflect a host of latent lifestyle and culture variables, which are not measured in the TUS-CPS (Edberg 2011).

7.2.3 Reduction of CPD to < 10 Per Day

7.2.2.1 Study Population

Smokers that stated they smoked less than 10 CPD per day, on average, at baseline were excluded from the sample. 1799 of the 2569 smokers in the total study sample met this inclusion criterion. Low intensity smoking is less stable than SFH. 50% of smokers reporting <10 CPD at baseline reported <10 CPD at follow-up (data not shown). Due to the CPD variable being one of the clustering variables, one cluster group, *Low intensity smokers*, was excluded from the analysis, due to 100% of members reporting a baseline CPD of less than ten.

7.2.2.2 Outcome Measure

The outcome measure of movement of smokers into the <10 CPD group was chosen over absolute reduction in CPD because it is associated with an increased chance of being successful if a quit attempt is made, as shown in chapter 4, Table 4.3.4, and improved health outcomes (Hellman et al. 1991; Hyland et al. 2006; Levy et al. 2005; Schane, Ling, and Glantz 2010). Further, smoking <10 CPD is associated with lower all-cause mortality and lower hazard ratios for smoking-related diseases such as lung cancer and respiratory disease (Inoue-Choi et al. 2016; Schane, Glantz, and Ling 2009). Finally, Zhu and colleagues (Zhu et al. 2003) reported that the <5 CPD group was less stable than daily and occasional smokers and suggested that the <5 CPD group was in transition. Consequently, <10 CPD was chosen to include a more stable group of low-rate smokers.

7.3 RESULTS

7.3.1 Univariate Analysis: Smoke-free Home Implementation

In unadjusted analyses, cluster group was significantly associated with implementation of a SFH (Table 7.3.1). Although *High dependence home smokers* home were least likely to implement a SFH during the study a significant proportion, 20.6% (C.I. 2.5), did so (Table 7.3.1). *Minority smokers* and *Low dependence moderate-heavy smokers* were similarly likely as one another to implement a SFH, (29.7%, C.I. 5.0, and 27.4%, C.I. 4.7 respectively) and *Low intensity smokers* were the most likely (33.6%, C.I. 6.8) (Table 7.3.1).

7.3.1.1 Identifying Covariates for Modeling

Smoke-free home implementation during the study was associated with a number of other variables in unadjusted analysis, many of which were significant at the 5% level: quit attempt during the study period, type of baseline home smoking rules, age, education level, and baseline self-efficacy to quit (Table 7.3.1). At the 25% level, timing of prior quit attempts and social support to quit in those who made an attempt also met the criteria for inclusion in regression modeling (Table 7.3.1). Two variables that did not meet the 25% F-to-enter criteria were included in the analysis for the purposes of controlling for societal level changes that have been associated with smoking-related behavior changes (Albers et al. 2007; Chaloupka, Yurekli, and Fong 2012; Cheng, Glantz, and Lightwood 2011; Hahn 2010). These were state-level comprehensive smoking bans in restaurants and state tobacco tax rate (Table 7.3.1).

7.3.2 Multivariate Analysis: Smoke-free Home Implementation

In adjusted analyses, two cluster groups, *Low intensity smokers and Minority smokers*, were significantly more likely to implement a SFH during the study period than the reference group, *High dependence home smokers*. *Low intensity smokers* and *Minority smokers* were almost equally likely to report a new SFH (AOR 1.50; 95% CI 1.02, 2.22; p=0.4 and AOR

1.51; 95% CI 1.14, 2.01; p=. 004, respectively) (Table 7.3.2). Making a quit attempt during the study was associated with an increased odds of SFH implementation (AOR 1.63; 95% CI 1.28, 2.07), while having attempted to quit smoking in the 12 months prior to baseline was associated with a decreased odds of implementing a SFH during the study (AOR 0.71; 95% CI 0.53, 0.95).

7.3.3 Univariate Analysis: Reduction to <10 CPD

Across the entire smoking population that did not report smoking <10 CPD at baseline, 23.2% reported smoking less than 10 CPD at follow-up (Table 7.3.3). This proportion was not uniform across cluster groups. While *Low dependence moderate-heavy smokers* and *Minority smokers* were more likely to achieve this meaningful reduction in CPD (33.6% and 34.2% respectively), the *High dependence home smokers* were the least likely to do so (16.3%)(Table 7.3.3).

The two cluster groups more likely to move to <10 CPD during the study also had the highest % of members in the 10-19 CPD at baseline. 64.5% of *Low dependence moderate-heavy smokers* in the study sample reported 10-19 CPD at baseline, as did 56.6% of *Minority smokers*. Whereas, 46.2% and 38.6% of *High dependence smokers with a SFH* and *High dependence home smokers* respectively, reported 10-19 CPD at baseline (Table 7.3.3).

Across the sub population that reported smoking 20+ CPD at baseline, 23.6% reported 10-19 CPD at follow-up (Table 7.3.3). This proportion was also not uniform across cluster groups. While *Low dependence moderate-heavy smokers* and *Minority smokers* were significantly more likely to report a reduction to the 10-19 CPD category (31.5% and 33.4 % respectively) than the *High dependence home smokers* (20.8%), the *High dependence smokers with a SFH* were similarly likely to report this change (24.2%) (Table 7.3.3). Making pairwise comparisons between the groups, and adjusting for multiple

comparisons, the trend for *Low dependence moderate-heavy smokers* and *Minority smokers* to behave alike and for *High dependence smokers with a SFH* and *High dependence home smokers* to behave similarly prevailed (Table 7.3.4).

7.3.3.1 Identifying Covariates for Modeling

Reducing CPD to move to the <10CPD group during the study was associated with a number of variables other than cluster group. Most variables tested were significant at the 5% level: making a quit attempt during the study, timing of prior quit attempts intention to quit, interest in quitting, self-efficacy to quit, age, education level, type of baseline home smoking rules, whether any other smokers lived in the house, and social supports during last quit attempt during the study period (Table 7.3.5). At the 25% level, tobacco tax also met the criteria for inclusion in regression modeling (Table 7.3.3). Two variables that did not meet the 25% F-to-enter criteria were included in the analysis for the purposes of controlling. These were gender, to account for known differences in smoking behavior between males and females and smoking ban in restaurants, to account for policy-level impacts on smoking-related behavior and social norms (Table 7.3.5).

7.3.4 Multivariate Analysis: Reduction to <10 CPD

7.3.4.1 Association Between Cluster Group and Moving to Light (<10 CPD) Smoking

In adjusted analyses (Table 7.3.6), two cluster groups, *Low intensity smokers* and *Minority smokers*, were significantly more likely to move to light smoking during the study than the reference group, *High dependence home smokers* (AOR 1.65; 95% CI 1.23, 2.23; p=.0009 and AOR 2.12; 95% CI 1.54, 2,90; p<.0001, respectively) (Table 7.3.6). Making a quit attempt during the study was associated with a large increase in odds of reducing CPD to less than 10 (AOR 6.17; 95% CI 4.85, 7.86). Having attempted to quit smoking at any time in the past was associated with a decreased odds of implementing a SFH, with those who made

an attempt in the 12 months prior to baseline similarly likely to reduce CPD as those having last made a quit attempt more than 12 months prior to baseline (AOR 0.65; 95% CI 0.51, 0.83 and AOR 0.71; 95% CI 0.54, 0.93, respectively) (Table 7.3.6).

Table 7.3.1 Univariate Analysis of SFH Implementation Between Baseline and Follow-Up (N=1377)

	Population			Total SFH at follow-up (n=336)			
Independent Variables	N	%	CI	N	%	CI	P-value
Cluster group							
High dependence home smokers	700	47.1	2.1	138	20.6	2.5	
Low intensity smokers	164	11.0	1.4	49	33.6	6.8	
Low dependence moderate-heavy smokers	252	18.7	1.6	74	27.4	4.7	
Minority smokers	261	23.1	1.9	75	29.7	5	<. 0001
Quitting Behavior							
Quit Attempt During Study							
No	812	59.0	2.2	165	21.9	2.7	<. 0001
Yes	565	41.0	2.2	171	30.5	3.2	
Baseline Timing of Prior Quit Attempts							
Never tried to quit	525	40.2	2.3	131	28	3.4	0.0671
Made attempt, > 12 months ago	301	19.7	1.6	71	22.7	3.6	
Made attempt within last 12 mo.	551	40.1	2.2	134	24.2	3.1	
Quitting Cognitions							
Quitting intention							
Plan to quit in next month	154	12.0	1.5	43	24.9	6.4	0.4875
Plan to quit in next 2-6 month	305	21.5	1.8	72	28	5	
No intent to quit	918	66.5	2.0	221	24.7	2.5	
Interest in quitting							
Low interest	529	38.4	2.2	128	46.3	3.6	0.7908
Moderate interest	437	31.9	2.2	101	25.9	3.6	
High interest	411	29.7	2.0	107	24.8	3.3	
Self Efficacy to Quit							
Low self-efficacy	131	9.4	1.3	86	23.8	4.0	0.0041
Moderate self-efficacy	632	46.5	2.3	35	31.5	7.2	
High self-efficacy	244	17.6	1.6	148	23.0	2.5	
No interest in quitting	370	26.4	1.9	67	31.2	4.9	
Demographics							
Race/ethnicity							
Hispanic	54	3.5	0.8	16	22.1	8.3	<. 0001
Non-Hispanic White	1116	76.9	1.9	261	24.2	2.3	
Non-Hispanic Black	162	14.0	1.6	39	24.3	5.8	
Asian/Other	45	5.6	1.3	20	47.9	12.4	

Table 7.3.1 Univariate Analysis of SFH Implementation Between Baseline and Follow-Up (N=1377)

	Population			Total SFH at follow-up (n=336)			
Independent Variables	N	%	CI	N	%	CI	P-value
Age							
18-29	120	17.6	2.4	39	32.5	7.2	0.0004
30-49	531	37.2	2.2	144	27.6	3.5	
50-64	560	34.6	2.0	118	20.7	2.3	
65+	166	10.6	1.1	35	21.5	4.9	
Education							
< H. S. grad	255	20.4	1.8	50	19.3	4.0	0.0037
H.S. grad	580	40.4	1.9	137	25.6	3.3	
Some college	380	28.7	1.9	101	29.5	3.8	
College grad	162	10.5	1.2	48	25.7	5.3	
Gender							
Male	625	51.6	2.4	145	25.2	3.1	0.7929
Female	752	48.4	2.4	191	25.7	2.5	
Personal Environment							
Type of Baseline Home Smoking Rules							
Partial SFH	556	37.0	2.1	180	33.8	3.8	<. 0001
No restrictions	821	58.7	2.2	156	20.2	2.4	
Household composition							
Sole smoker	913	63.9	2.6	233	25.1	2.3	0.6931
Other smokers in HH	464	36.1	2.6	103	26	4.0	
Social support for quit							
No	1217	87.7	1.6	293	24.8	2.3	0.1187
Yes	160	12.3	1.6	43	30.2	6.6	
Societal Environment							
Taxes							
High tax	358	21.6	1.8	101	27.5	4.1	0.8408
Medium tax	549	44.0	2.4	154	27.4	3.1	
Low tax	470	34.4	2.5	124	26.2	3.5	
Restaurant ban							
Smoke-free	839	57.9	2.6	209	26.2	2.6	0.4236
Not Yet Implemented	538	42.1	2.6	127	24.5	3.3	

Table 7.3.2 Logistic Regression Predicting SFH Implementation Between Baseline and Follow-Up

Independent Variables	Predicting smoke-free home implementation among all smokers without a SFH at baseline (n=1377) OR	Confidence limits		P-value
Cluster group				
High dependence home smokers (n=700)	Ref.			
Low intensity smokers (n=164)	1.50	1.02	2.22	0.040
Low dependence moderate-heavy smokers (n=252)	1.29	0.96	1.74	0.088
Minority smokers (n=261)	1.51	1.14	2.01	0.004
Baseline Home Smoking Allowed				
Some Places	1.85	1.45	2.36	0.000
Everywhere	Ref.			
Quit Attempt During Study				
Yes	1.63	1.28	2.07	0.000
No	Ref.			
Timing of Prior Quit Attempts				
Made attempt within last 12 months	0.71	0.53	0.95	0.020
Made attempt, > 12 months ago	0.79	0.6	1.03	0.082
Never attempted to quit	Ref.			

Controlling for: Age, Education, Gender, Quitting Self Efficacy, Live With Other Smokers, Taxes, Smoke-free Restaurants, and Social Support for Quit.

Note: Interaction term of Cluster group*Baseline Home Smoking Rules was tested during the modeling process and was insignificant. Both variables also tested negative for confounding.

Table 7.3.3 CPD Groups Change Between Baseline and Follow-Up by Cluster group

	Study Population		% Move to <10 CPD		% Move to 10-19 from 20+		% 10-19 Baseline CPD Category	
Cluster group	n	% of population	%	p	%	p	%	p
High dependence home smokers	699	38.9	16.3	Ref.	20.8	Ref.	38.6	Ref.
High dependence smokers with a SFH	377	21	19.7	0.075	24.2	0.098	46.2	0.000
Low dependence moderate-heavy smokers	488	27.1	33.6	0.000	31.5	0.000	64.5	0.000
Minority smokers	235	13.1	34.2	0.000	33.4	0.002	56.6	0.000
Total Population	1799	100	23.2		23.6		45.7	

Table 7.3.4 Significance of Pairwise Comparisons with α Adjusted for Multiple Comparisons

	% Move to <10 CPD	% Move to 10-19 from 20+
Cluster group	sig.	sig.
High dependence smokers with a SFH vs. High dependence home smokers	NS	NS
Minority smokers vs. High dependence home smokers home	*	*
Low dependence moderate-heavy smokers vs. High dependence home smokers	*	*
High dependence smokers with a SFH vs. Minority smokers	*	NS
High dependence smokers with a SFH vs. Low dependence moderate-heavy smokers	*	NS
Minority smokers vs. Low dependence moderate-heavy smokers	NS	NS

NS not significant

Table 7.3.5 Univariate Analysis of Reduction of CPD to <10 CPD at Follow-Up (N=1477)

Independent Variables	Population			Total <10 CPD at follow-up (n=423)			P-value
	N	%	CI	N	%	CI	
Cluster group							
High dependence home smokers	700	36.0	1.6	114	16.3	2.2	
High dependence smokers with a SFH	377	20.7	1.5	81	19.7	3.4	<.0001
Low dependence moderate-heavy	488	27.6	1.7	151	33.6	3.3	
Minority smokers	234	15.7	1.3	77	34.2	4.6	
Quitting Behavior							
Quit Attempt During Study							
No	1071	58.2	1.9	118	11.7	1.5	<.0001
Yes	728	41.8	1.9	305	42.5	3	
Baseline Timing of Prior Quit							
Never tried to quit	672	39.4	1.8	148	23.9	2.5	0.0137
Made attempt within last 12 mo.	709	38.8	1.9	196	27.4	2.9	
Made attempt, > 12 months ago	418	21.7	1.3	79	20.9	3.1	
Quitting Cognitions							
Quitting intention							
Plan to quit in next month	190	10.9	1.3	64	34.1	6.5	0.001
Plan to quit in next 2-6 month	415	23.0	1.7	100	25.5	3.5	
No intent to quit	1194	66.1	2.1	259	22.7	2.0	
Interest in quitting							
Low interest	690	38.2	1.8	142	46.3	3.6	<.0001
Moderate interest	562	31.3	1.6	125	22.8	3.1	
High interest	547	30.5	1.8	156	30.4	3.0	
Self Efficacy to Quit							
Low self-efficacy	154	8.1	1	26	18.4	4.9	0.007
Moderate self-efficacy	836	47	1.9	213	25.5	2.7	
High self-efficacy	301	16.5	1.5	81	29.5	4.6	
No interest in quitting	508	28.4	1.7	103	21.9	2.9	
Demographics							
Race/ethnicity							
Hispanic	76	4	0.7	22	36.8	9.8	0.0002
Non-Hispanic White	1560	83.7	1.3	346	22.9	1.7	
Non-Hispanic Black	111	7.8	1	36	30.3	6	
Asian/Other	52	4.5	0.8	19	34.5	9.6	

Table 7.3.5 Univariate Analysis of Reduction of CPD to <10 CPD at Follow-Up (N=1477)

Independent Variables	Population			Total <10 CPD at follow-up (n=423)			P-value
	N	%	CI	N	%	CI	
Age							
18-29	177	17.8	1.8	53	31.4	5.3	0.0005
30-49	754	40.4	1.7	170	23.5	2.2	
50-64	690	32.9	1.6	153	21.8	2.3	
65+	178	8.9	0.8	47	26.1	4.5	
Education							
< H. S. grad	290	16.9	1.4	60	19.7	3.8	0.0011
H.S. grad	767	42.2	1.7	166	23.5	2.1	
Some college	539	30.2	1.6	146	28.9	3.3	
College grad	203	10.6	1.1	51	24.2	4.2	
Gender							
Male	871	54.2	1.8	191	24.5	2.2	0.9241
Female	928	45.8	1.8	232	24.7	2.1	
Personal Environment							
Type of baseline home smoking SFH							
Total SFH	694	39.9	1.9	200	29.8	2.8	<.0001
Not SFH	1105	60.1	1.9	223	21.1	2.2	
Household composition							
Sole smoker	1175	64.2	2.2	305	26.5	2.1	0.0082
Other smokers in HH	624	35.8	2.2	118	21.1	3	
Social support for quit							
No	1569	86.5	1.5	334	22.4	1.6	<.0001
Yes	230	13.5	1.5	89	38.5	5.6	
Societal Environment							
Taxes							
High tax	448	21.1	1.5	118	28.2	3.9	0.0852
Medium tax	760	46.4	2.1	177	23.2	2	
Low tax	591	32.5	2	128	24.2	3.2	
Restaurant ban							
Smoke-free	1154	61.1	2.1	283	25.2	1.9	
Not Yet Implemented	645	38.9	2.1	140	23.7	2.7	0.394

Table 7.3.6 Logistic Regression Predicting CPD Reduction to <10 CPD Between Baseline and Follow-Up

	Predicting reduction in CPD to <10 (n=1799)			
Independent Variables	OR	Confidence limits		P-value
Cluster group				
High dependence home smokers (n=700)	Ref.			
High dependence smokers with a SFH (n=700)	0.68	0.44	1.04	0.07341
Low dependence moderate-heavy smokers (n=488)	1.65	1.23	2.23	0.0009
Minority smokers (235)	2.12	1.54	2.90	<.0001
Quit Attempt During Study				
Yes	6.17	4.85	7.86	<.0001
No	Ref.			
Timing of Prior Quit Attempts				
Made attempt within last 12 months	0.65	0.51	0.83	0.0004
Made attempt, > 12 months ago	0.71	0.54	0.93	0.0127
Never attempted to quit	Ref.			

Controlling for: Age, Education, Gender, Intention to Quit, Interest in Quitting, Quitting Self-Efficacy, Live With Other Smokers, Taxes, Smoke-free Restaurants, and Social Support for Quit.

7.4 DISCUSSION

7.4.1 Cluster group Differences in Smoke-free Home Implementation

Across the sub-population of smokers that reported smoking in all or some parts of their home at baseline, almost 25% reported a smoke-free home at follow-up. This represents a rapid rise in the rate of implementation of smoke-free homes. The baseline rate of SFHs is consistent with reports from another study using the same dataset (King et al. 2014). The rate of implementation of a SFH was not consistent between all groups. The finding that *Low dependence moderate-heavy smokers* and *High dependence home smokers*, both groups of moderate to heavy smokers, reported SFH implementation suggests that SFHs are becoming the social norm for the smoking population because high CPD is associated with lower rates of SFHs (Gilpin et al. 1999; Mills et al. 2009). Although the data does not indicate a reason for smoke-free home implementation, the trend for *High dependence home smokers* to change suggests that even heavy smokers, who are likely to be most inconvenienced by implementation a SFH, are following population level trends (King et al. 2014). *Low intensity smokers* and *Minority smokers* were significantly more likely to implement a smoke-free home than both the *High dependence home smokers* and the *Low dependence moderate-heavy smokers*, which is consistent with the literature that reports the association of light smoking (<10 CPD) and SFH. These two groups are the two lightest smoking cluster groups, with 54% of *Minority smokers* reporting a CPD of lower than ten at baseline and all of the *Low intensity smokers* doing so. The higher likelihood of SFH implementation could reflect the fact that lighter smokers can more easily adapt to smoking outside of the home because the frequency with which they will do so is less than heavier smokers (IARC Working Group 2009). In addition, *Low intensity smokers* are likely to be less nicotine dependent (Heatherton et al. 1991) and likely to have less intense cravings to smoke (Escoffery, Kegler, and Butler 2009), which would allow them to wait for a more convenient time to go outside to smoke and reduce

disruption to other activities. Finally, *Low intensity smokers* are most likely to make a quit attempt during the study (Chapter 6, Table 6.3.1), which is associated with SFH in both this study and the literature (Gilpin et al. 1999; Mills et al. 2009; Rose et al. 2011).

7.4.2 Cluster group Differences in Reduction of Smoking Intensity to <10 CPD

Across the sub-population of smokers that reported smoking 10+ CPD at baseline, over 20% reported smoking less than 10 CPD at follow-up, for the majority, reduced CPD was likely to be part of a failed quit attempt as the odds of decreasing CPD to <10 for those who made a quit attempt compared to those who did not was large, (AOR 6.17; 95% CI 4.85, 7.86). However, this rate was not consistent between cluster groups, which divided into two distinct groups with different rates of reduction to <10 CPD. The two groups were clusters characterized by high dependence and clusters characterized by low dependence. The absolute rate of reduction of CPD to less than 10 was lower in the cluster groups characterized by high dependence. These were the *Heavy smokers with a smoke-free* and the *High dependence home smokers.* Despite reporting a lower rate of CPD reduction than the other cluster groups, almost 20% of the *Heavy smokers with a smoke-free* and over 16% of *High dependence home smokers* made the reduction to less than 10 CPD. In addition, the rates at which members of these groups were moving to 10-19 CPD from 20+ was over 20%. This suggests a diffusion effect to lower cigarette consumption across the whole smoking population, which is consistent with reports from the CDC (Agaku, King, and Dube 2014) is consistent with changes in SFH. This trend doesn't necessarily mean that smokers with high dependence were able to reduce their smoking to <10 CPD in the future. It could be that highly dependent smokers have found a default CPD between 10 and 19 CPD, at which they can control nicotine cravings. In this scenario, these smokers would return to the default CPD after a failed QA, which could be a reduction from their CPD prior to their failed attempt (Marlatt and Gordon 1985).

Having a SFH did not appear to significantly change the likelihood of reducing to <10 CPD in the high dependence smokers who smoked 10 or more CPD at baseline, as the *High dependence smokers with a SFH* were no more likely to make the reduction to <10 CPD than the *High dependence home smokers.* This is contrary to many previous studies that report a positive association between living in a SFH and reduced cigarette consumption across the smoking population (IARC Working Group 2009; Messer et al. 2008; Mills et al. 2009, 2011). However, this association may be attenuated in high dependence smokers because they have adapted to a smoke-free home (Messer et al. 2008) and may be more willing to be inconvenienced to satisfy cravings. Further research into the reasons that *High dependence smokers with a SFH* implemented the SFH prior to baseline and what adaptions they have made to their smoking behavior as a result would help with understanding this finding. It is possible that for some *High dependence smokers with a SFH* the SFH is a relic of a previous failed quit attempt and changing dependency through pharmaceutical interventions and counseling may improve cessation rates in this group (Cahill et al. 2013). However, this explanation does fully not account for the equity in smoking behavior between *High dependence smokers with a SFH* and *High dependence home smokers* because *High dependence smokers with a SFH* were no more likely to have made a quit attempt in the recent or distant past than the *High dependence home smokers* (Table 6.3.5).

Low dependence moderate-heavy smokers and *Minority smokers* were significantly more likely to reduce their CPD to less than 10 than both the *High dependence home smokers* and *Heavy smokers with a smoke-free*. This is inconsistent with the literature, which reports that smokers with a SFH were more likely to make a QA and more likely to reduce to their CPD (Mills et al. 2009).

The key limitation to this chapter was the exclusion of 70 respondents from the SFH implementation analysis due to missing follow-up data.

7.5 CONCLUSION

The findings from this study show that cluster groups are not equally likely to implement a SFH or reduce CPD to light smoking (<10). The results did not suggest that smokers in subgroups with higher baseline prevalence of the outcomes had already implemented a SFH or reduced to light smoking if they were going to. On the contrary, members of subgroups with high baseline prevalence of outcomes that had not yet made the changes were the most likely to report the outcomes at follow-up. This suggests within-subgroup diffusion.

While making a QA during the study was the dominant predictor of reduced CPD, after controlling for QA, significant differences between subgroups in the odds of reducing to <10 CPD remained. The low dependence subgroups included in the reduced CPD analysis, *Low dependence moderate-heavy smokers* and *Minority smokers*, were significantly more likely to reduce to light smoking than *High dependence home smokers,* while *High dependence smokers with a SFH*, were equally likely. Further research is needed to understand the differences between the high dependence groups and why living in a SFH and being more likely to make a quit attempt appears to confer little benefit to the *High dependence smokers with a SFH* with respect to the harm-reducing behaviors, reducing CPD and achieving 30D-A if a quit attempt is made.

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CHAPTER EIGHT

Discussion

8.1 BACKGROUND

Smoke-free homes and light cigarette consumption are associated with successful cessation. Over the past couple decades there has been an increase in the prevalence of smoke-free home and a decrease in average cigarette consumption. However, these trends have not been associated with changes in the cessation rate, suggesting the relationships between these and other smoking-related variables with cessation may be changing. The purpose of this study was to identify homogeneous subgroups of smokers and compare changes in quitting behaviors, cigarettes per day (CPD), and smoke-free homes over following year.

8.2 RESEARCH FINDINGS

8.2.1 Research Objective #1: To identify whether the 2010/11 smoking population can be clustered into subgroups based on the factors independently associated with QA and 30D-A (outcome variables).

Identifying variables associated with quitting behavior outcomes in a real world population is an important first step in the study of the population-level trends of smokers. By design, a lot of the research into smoking cessation behaviors has taken place as part of prospective studies, which usually enroll a subset of the smoking population, limiting the external validity of their findings. Empirically testing the associations of variables identified in an update of the systematic review conducted by Vangeli and colleagues (2011) (Vangeli et al. 2011), along with the variables identified in the original review, suggested that the individual level correlates of quitting behaviors are fairly stable over time and that, in general, many of the same variables, predict quit attempt and 1 month abstinence. This is despite constantly changing patterns of smoking-related behaviors and social acceptance of smoking (Cummings and Proctor 2014).

The cluster analysis identified four variables that frequently cluster together to create a taxonomy, which classified smokers into a subgroup based on clear empirical characteristics: smoking intensity, nicotine dependence, home smoking rules, and race/ethnicity. The classification of smokers resulted in five sub-groups, four of which were characterized by the combination of their smoking intensity (CPD), nicotine dependence, and SFH status: *High dependence home smokers* (n=700, Group 1 ref), *High dependence smokers with a SFH* (n=458, Group 2), *Low intensity smokers* (n=446, Group 3), *Low dependence moderate-heavy smokers* (n=488, Group 4). One cluster grouped all racial/ethnic *Minority smokers* (n=477) irrespective of their behavior pattern.

Although the cluster groups identified were not fully homogeneous, they were mutually exclusive and provided insight into the most salient variables associated with quitting behaviors in different sub-groups of smokers. The most well differentiated sub-group included the most dependent smokers, who smoked at home, and reported the highest smoking intensity. The least homogenous group included the smokers reporting Hispanic, Non-Hispanic Black, Asian, or Other race/ethnicity. Some of the cluster groups also differed with respect to other variables associated with smoking behavior and cessation. The most notable difference between cluster differences were seen in the age, education level, quit intention, quitting history, and smoke-free restaurants in state of residence variables, suggesting personal, behavioral, and environmental level associations.

8.2.2 Research Objective #2: To verify that smoker subgroups identified by this cluster analysis vary significantly in the odds of QA and abstinence.

Consistent with findings from the analysis of the independent associations of predictors with smoking behavior outcomes, the sub-group least likely to make a quit attempt or report 30D-A was the *High dependence home smokers*, who also reported the highest smoking intensity. The group most likely to make an attempt and report 30D-A was the *Low*

intensity smokers, most of whom also reported low dependence. Together, *this suggests that importance of each clustering variable is inconsistent across the sub-groups*, and the combinations of variables identified by the cluster analysis are potentially important in smoking cessation.

Low nicotine dependence appears to negate the effects of a SFH on smoking and quitting behavior. Given low dependence, only smoking intensity drives cluster group and assignment and associated odds of outcomes. That said, both *Low intensity smokers* and *Low dependence moderate-heavy smokers* have increased odds of QA and 30D-A, which suggests that low dependence alone may be associated with positive quitting outcomes. The continuation of smoking at a rate of more than 10 CPD in the *Low dependence moderate-heavy smokers* is of interest, especially given the increasing cost of cigarettes, the well-evidence price elasticity of cigarette consumption, and the diffusion of anti-smoking social norms (Chaloupka et al. 2002; Chaloupka, Levy, and Huang 2011; Gilpin, Lee, and Pierce 2004; Keeler et al. 1993; Zhang, Cowling, and Tang 2010). However, this group are the most likely to state to they have intention to quit and may be unaffected by societal level changes.

While, as can be seen, dependence was very important in the classification of smokers, in multivariate analyses evaluating the independent effects of variables on QA and 30D-A, the dependence variable was not significant at the 5% level in either model. This is an example of the complementary nature of cluster analysis and regression: cluster analysis can highlight the importance of relationships between variables that may not be tested in regression.

8.2.3 Research Objective #3a: To evaluate whether the clusters predict SFH implementation in those without a SFH at baseline

Research Objective #3b: To evaluate whether the clusters predict CPD reduction to light smoking in those who smoke >10 CPD at baseline.

Given high dependence, the combination of smoking intensity and smoke-free home are important in classification into cluster group and associated differential outcomes. For smokers with high dependence and moderate or heavy smoking intensity, a combination that is associated with both physical and psychological dependence (Schane, Glantz, and Ling 2009), the addition of a smoke-free home appears to be insufficient to improve reduced CPD and, in those who make a quit attempt, 30D-A outcomes. This is evidenced by the equal likelihood of *High dependence smokers with a SFH* and *High dependence home smokers* to report reduced CPD and 30D-A given an attempt to quit. The combination of high dependence and SFH is associated with increased odds of making a quit attempt however, as the *High dependence smokers with a SFH* are significantly more likely to make a quit attempt than *High dependence home smokers*.

The importance of a QA is illustrated throughout the analysis, including reducing CPD. For example, only 12% of those who smoked 10+ CPD at baseline reduced their CPD to < 10 in the absence of a QA. The results demonstrate that making a quit attempt, both successful and unsuccessful, is a key driver of reducing CPD to <10. This is consistent with findings that suggest CPD tends to be reduced for several months after a failed quit attempt (Knoke, Anderson, and Burns 2006; Yong et al. 2008). Yong and colleagues (Yong et al. 2008) noted a range of post-failure consumption changes to a failed quit attempt. They reported that almost half of those who relapse reduced their consumption by less than 5% over the 7 month follow up period, which even a 20 CPD smoker is only a 1 cigarette per day reduction. The finding that *High dependence smokers with a SFH* are no more likely to reduce their consumption than *High dependence home smokers* suggests that in heavy, high dependence smokers, a SFH does not encourage the maintenance of lower CPD after a failed quit attempt.

The impact of a SFH is dependent upon the other characteristics it is exhibited with, another example of how the importance of a clustering variable changes dependent upon co-occurring factors. The finding that *High dependence smokers with a SFH* are no more likely to reduce their consumption than *High dependence home smokers* suggests that in heavy dependent smokers, a SFH does not encourage the maintenance of lower CPD after a failed quit attempt. However, for smokers with high dependence and low intensity, the impact of a SFH is more marked. While those with a SFH are assigned to the *High Dependence Smokers with a SFH*, those without a SFH are classified as *Low intensity smokers*. The odds of 30D-A given a quit attempt are significantly higher in *Low intensity smokers* than *High Dependence Smokers with a SFH*. One hypothesis that requires further information to test is that the *High Dependence Smokers with a SFH* have a temporarily lowered CPD, which is sometimes seen after a failed quit attempt, as discussed above (Knoke et al. 2006). For the *Low intensity smokers* reporting high dependence and no smoke-free home, it is possible they are psychologically dependent, but not physiologically dependent. Consequently, if they try to make changes to their smoking behavior, such as implementing a SFH, or try to quit, they do not have to go through the symptoms associated with the physical withdrawal of nicotine (DiFranza, Huang, and King 2012; Killen et al. 1992). Removing the effects of withdrawal removes a significant barrier to cessation, which would result in increased success with change.

For smokers with high dependence and low intensity, the impact of a SFH is more marked. While those with a SFH are assigned to the *High Dependence Smokers with a SFH*, those with no SFH are classified as *Low intensity smokers*. The odds of 30D-A are significantly higher in *Low intensity smokers* than *High Dependence Smokers with a SFH*. It is possible that the *High Dependence Smokers with a SFH* have a temporarily lowered CPD, which is sometimes seen after a failed quit attempt, as discussed above (Knoke et al. 2006).

This would distort the relationship between dependence and CPD because, without the failed attempt, these smokers might smoke 10+ CPD like the other members of the cluster group. For the *Low intensity smokers* reporting high dependence and no smoke-free home, it is possible they are psychologically dependent, but not physiologically dependent. Consequently, if they try to make changes to their smoking behavior, such as implementing a SFH, or try to quit, they do not have to go through the symptoms associated with the physical withdrawal of nicotine (DiFranza et al. 2012; Killen et al. 1992). Removing the effects of withdrawal removes a significant barrier to cessation, which would result in increased success with change.

Low nicotine dependence appears to negate the effects of a SFH on smoking and quitting behavior. Given low dependence, only smoking intensity drives cluster group and assignment and associated odds of outcomes. That said, both *Low intensity smokers* and *Low dependence moderate-heavy smokers* have increased odds of QA and 30D-A, which suggests that low dependence alone may be associated with positive quitting outcomes. The continuation of smoking at a rate of more than 10 CPD in the *Low dependence moderate-heavy smokers* is of interest, especially given the increasing cost of cigarettes, the well-evidence price elasticity of cigarette consumption, and the diffusion of anti-smoking social norms (Chaloupka et al. 2002, 2011; Gilpin et al. 2004; Keeler et al. 1993; Zhang et al. 2010). However, this group are the most likely to state to they have intention to quit and may be unaffected by societal level changes.

Overall, for continuing smokers who make a failed quit attempt or did not try to quit and continue to smoke in a time where most public places have smoking restrictions and smoking at home is increasingly outside of social norms appear to fall into one of two categories: those who adapt to the changes and those who respond to the changes. It is possible that some smokers that implement a SFH and reduce their CPD will reduce their

consumption to the minimum level their high dependence allows, while other smokers, the responders, will implement a SFH and reduce their CPD resulting in cessation. The three cluster groups *Less-dependent heavier smokers*, *High dependence smokers with a SFH*, and *Heavy smokers without a smoke-free home* provide a framework for testing this hypothesis, which would predict an continued increase in SFH prevalence and light smoking, but much smaller increases in cessation rate.

8.3 IMPLICATIONS OF FINDINGS

8.3.1 Research Implications

Research Question: Does segmenting the smoking population by combined personal, environmental, and personal environment characteristics provide new insights into the types of smoker more likely to engage in quitting or harm-reducing behaviors?.

In a time of rapidly changing smoking-related behavior, undertaking studies to understand the changing profile of the smoking population and their smoking and quitting behaviors is needed. This is one of those times, when we find changes in cigarette consumption (Pierce et al. 2010; Pierce, White, and Messer 2009), implementation of SFHs (King, Patel, and Babb 2014), public smoking restrictions (Anger, Kvasnicka, and Siedler 2011; Zablocki et al. 2014), and e-cigarette use (Al-Delaimy et al. 2015; Rigotti 2015; Shi et al. 2016).

Identifying common patterns of behavior associated with smoking and quitting related behavior, which may be shared by numerous demographic or comorbid groups, could be useful in designing interventions that are targeted to sub-groups of the population but are broadly applicable enough to have the resources to be developed and implemented.

As different subgroups of smokers respond to the changing tobacco environment in different ways, a one-size-fits all policy may be less effective. For example, low dependence smokers may not increase their odds of cessation by gradually reducing their CPD,

implementing a SFH, or using pharmacological interventions. Instead, formative research into possible psychological addiction to smoking and the reasons low dependence groups have not yet quit could generate new targets for intervention. For high dependence smokers, gradual, achievable changes, such as reduction of CPD could result in improvement in self-efficacy to quit. This may be more effective in improving quit rates in the long term. In addition, improving availability of nicotine replacement products to the high dependence smokers through prioritizing smoking cessation counseling in the primary care setting may improve cessation rates.

A key finding from this work is that the cluster groups provide insights that are missed from a standard regression. As mentioned above, the *importance of each clustering variable is inconsistent across the sub-groups*. For example, "dependence" was not significant at the 5% level in either the QA or 30D-A model, but was selected as a cluster candidate variable due to a broad inclusion criteria. It appears to be as a mediator of the effects of smoking intensity, and to a lesser extent SFH, on the outcome variables. This type of relationship, which may be important in selecting interventions, can be missed in a standard regression.

The cluster groups also provide a framework for future research by identifying comparison groups for study. For example, comparing the effectiveness of an intervention in the *High dependence smokers with a SFH* and *High dependence home smokers* would provide insights into the importance of having a SFH on the effectiveness of an intervention in high dependence smokers. If a SFH significantly improved effectiveness, the implementation of a SFH could be a first stage of the intervention.

8.3.2 Policy Implications

The conventional way to measure change across the smoking population uses outcome measures that are averaged across all smokers (Peck 2005). However, this approach hides differences across the smoking population and is also susceptible to the influence of outliers.

As documented in this work, the 2010/11 smoking population was heterogeneous with respect to many individual characteristics, cognitions, home environment, interpersonal relationships, community norms, and exposure to tobacco control policies. Consequently, identifying trends in outcomes of interest for every combination of variables that influence each outcome would be impractical. By clustering similar combinations of the important baseline characteristics together into sub-groups, policy makers have identifiable groups for use in targeting interventions and for further research.

Identifying sub-groups of smokers that were more likely to quit unaided, possibly in response to the combination of population-level interventions, such as mass media campaigns, and societal norms, could allow practitioners to focus on those at highest risk for continuing to smoke. In this study, *high dependence home smokers* were the least likely to make a quit attempt and the most prevalent group. They were also one of three groups with relatively lower odds of achieving 30D-A if a quit attempt was made, along with *high dependence smokers with a SFH* and *minority smokers*. These results suggest that interventions aiming to improve the chances of a smoker making a quit attempt could be most appropriate for *high dependence home smokers*, while *minority smokers* may be more likely to benefit from interventions that aim to improve quit success, given an attempt.

In addition to identifying otherwise difficult-to-identify subgroups (Peck 2005), clusters are also useful in the evaluation of the effectiveness of interventions and programs. The findings of this study suggest that some sub-groups were more likely to achieve each of the four outcome measures without intervention, (QA, 30D-A, SFH implementation, and reduced CPD to less than 10), than others. Consequently, the potential for incremental benefits of intervention is greater in some sub-groups than others (Macias et al. 2008).

The advantage of using cluster groups in intervention studies is two-fold. Firstly, different intervention targets may be indicated for different sub-groups, for example, SFH does not appear to significantly improve the odds of 30D-A in the low dependence subgroups. This suggests that an intervention that targets SFH implementation in order to improve 30D-A rate would not be as effective in low dependence sub-groups as high dependence subgroups, who are more likely to make an attempt to quit if they have a SFH and thus more likely too achieve 30D-A overall. Secondly, conducting effectiveness studies on specific sub-groups ensures that findings identify which group an intervention is more likely to be effective in based on the efficacy of the intervention to elicit change in the outcome measure in a sub-group and the odds of those changes being made without intervention (Macias et al. 2008).

Overall, cluster analysis has the potential to identify sub-groups that would be difficult to identify otherwise, could provide information about the most appropriate targets for intervention in the different sub-groups, and could help to prioritize the availability of each intervention to the smokers that are most likely to benefit.

8.4 SUMMARY OF LIMITATIONS AND RECOMMENDATIONS

There were a number of limitations associated with this study as whole. First, the sample size of smokers that did not report Non-Hispanic White Race/Ethnicity (R/E) meant that the combinations of race/ethnicity group and the personal, behavioral, and personal environment factors associated with cessation could not be elucidated by the cluster analysis. This meant that all groups other than Non-Hispanic White were clustered into one group (*Minority smokers*). The heterogeneous nature of smoking behavior in the *Minority smokers* group precluded meaningful interpretation. Future research into sub-groups of smokers in minority ethnic populations should undertake analysis of each R/E separately, as the patterns of behavior are very different in the different R/E groups. This would require a large sample for each R/E group, which may be difficult to operationalize. It may be more effective to take

a qualitative approach to identifying subgroups in minority ethnic smokers. A qualitative approach has been taken in identifying subgroups of patients with a specific disease (Lynn et al. 2007), where recruiting a big enough sample for empirical cluster analysis may be challenging.

Second, not including the self-efficacy variable as a candidate in the cluster solution excludes one of the key constructs on which the social cognitive theory is based. The reasons for exclusion, missing data due the skip pattern of the survey and use of a one-item measure with questionable validity (Bandura 2006; de Vries 2016), are reasonable. However, despite recent controversy over the predictive validity and mechanism of action of self-efficacy in behavior change (Gwaltney et al. 2009; de Vries 2016; Williams and Rhodes 2016), the variable has long been associated with smoking cessation behaviors (Haug et al. 2010; Partos et al. 2013; Vangeli et al. 2011). The exclusion of this construct could have reduced the explanatory and predictive power of the cluster groups (Bandura 1978). Adding a multi-item validated self-efficacy variable into the TUS-CPS that is administered to all respondents would allow the addition of this variable to the cluster analysis.

Third, the prior quit attempt variable did not capture the specific timing of the last quit attempt and did not allow identification of the length of the last quit. This meant that it was not possible to derive any information about the likely physiological withdrawal associated with the last quit attempt at baseline (DiFranza et al. 2012; Killen et al. 1992). All of the aforementioned variables have been associated with cessation behavior and simplifying the variable may have reduced the explanatory value of the construct (Partos et al. 2013). However, although this data is collected in the TUS-CPS, it is known to be subject to strong recall bias, especially when related to more distal and shorter quit attempts, which further would result in under-reporting and introduce bias (Berg et al. 2010; Gilpin and Pierce 1994).

Monthly data collection would improve the impact of recall bias, however, this is likely to be impractical.

A further limitation was the use of <10 CPD as a light smoker. It is well documented that the population of those smoking <10 CPD included daily light smokers, some-day smokers, and occasional smokers, and that these groups exhibit different quitting behaviors (Edwards et al. 2010; Shiffman 1989; Shiffman et al. 2015; Tindle and Shiffman 2011). By aggregating these different smoker patterns into one group, potentially important variation was lost. However, the health outcomes associated with all <10 smokers are not materially different to one another but are significantly different to former smokers (Inoue-Choi et al. 2016), suggesting physiological effects of the group are relatively similar and providing validity to grouping them. Going forward, as more smokers reduce their CPD and move into the <10 CPD category, elucidating the different types of light smokers may be indicated because the sample sizes for each type of light smokers will grow, making meaningful analysis possible.

Finally, cluster analyses are influenced by the choice of candidate variables, which is partially subjective. This study aimed to take an evidence-based approach to candidate variable selection, but due to data availability and measurement issues, excluded a number of variables from the candidate variable set. In addition, cluster analysis is a data-driven method, designed to provide new insights into subgroups in a population, which can be useful in the design of interventions and to generate hypotheses for future research. Consequently, the findings are unlikely to be generalizable over time if trends in smoking-related behaviors change. Testing the reliability of the cluster analysis in a different dataset, data collected in the same general period of time would confirm whether the clusters are robust.

Technical limitations specific to analysis and measurement in individual chapters are discussed in the relevant chapter.

8.5 CONCLUSION

Smoking prevalence has steadily declined since the Surgeon General's report of 1964, however, this decline is predominantly driven by the decline in smoking initiation in young people (CDC 2015); smoking cessation rates have been stable for the last 20 years.

Changing smoking behavior and quitting smoking are notoriously difficult. Consequently, understanding the factors that influence smokers' likelihood of making changes and capitalizing on this knowledge to augment the influence of these factors is of value. However, all external influences do not have the same effect in all smokers. This heterogeneity of effect is the result of reciprocal personal, behavioral, and environmental determinants, which exert differential influence in different people. Clearly, a large number of factors influence smoking behavior and the number of possible permutations that can occur in a given individual are immense. That said, across the whole smoking population, not all factors are equally important. Having empirically identified a small number of the most important factors and compared the behavior change (attempt to quit, abstinence, SFH implementation, reduced CPD) of the smokers exhibiting these characteristics, it may be possible to target smokers to make the most effective changes for their profile. While population level changes to external stimuli, such as changing social norms, increased awareness of smoking harms, and imposed smoking restrictions, may be sufficient to evoke changes in smoking-related behavior, translating these changes into cessation appears to be more challenging. Helping smokers to modify their personal, behavioral, and environmental responses to external stimuli and quit smoking may require different approaches to messaging and intervention, depending upon those responses.

This study provides a proof of concept for using cluster analysis to identify sub-groups in the smoking population and provides a framework for further research into augmenting the most salient factors for different smoker subgroups. Future studies may use a

mixed methods approach to build a richer understanding of the subgroups and to further test their operational validity. Qualitative studies may be the most appropriate way to capture the relationships of cognition variables with other personal, behavioral, and environmental variables, given the challenges in measuring these variables and their theoretical importance.

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