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Investigating the Mechanisms of Smoking Behavior Change With Statistical Mediation Analysis

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INVESTIGATING THE MECHANISMS OF SMOKING BEHAVIOR CHANGE WITH STATISTICAL MEDIATION ANALYSIS

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ABSTRACT

Investigating and quantifying the mechanisms that underlie behavior change is essential to understanding what drives effective interventions. Cigarette smoking remains a critical concern for public health, and increasing basic knowledge of smoking behavior change can directly lead to improved interventions. This series of six studies represents a comprehensive evaluation of the mechanisms of smoking behavior change with statistical mediation analysis. All studies utilized combined data from five tailored interventions based on the Transtheoretical Model (TTM) for participants in Precontemplation (PC; N = 1145), Contemplation (C; N = 1243), and Preparation (PR; N = 499). Statistical mediation models under investigation were autoregressive, three-wave models (baseline, 12 months, and 24 months) developed within each stage of change. The ten Processes of Change for Smoking were used as independent variables, Pros of Smoking, Cons of Smoking, and Situational Temptations to Smoke were used as mediators, and a behavioral smoking outcome was used as the dependent variable.

Studies 1, 2, and 3 investigated single mediator models at PC, C, and PR, respectively. Across the three stages, a total of 25 single mediator models, each with different combinations of variables, demonstrated evidence of statistical mediation. Studies 4 and 5 refined, consolidated, and extended the conclusions from these single mediator models. Study 4 found evidence of statistical mediation in multiple mediator models, and study 5 found evidence of statistical mediation in models with multiple Processes of Change for Smoking, resulting in a total of 20 final models. In study 6, the final models were tested for the presence of statistical moderation. Factorial invariance techniques were utilized to evaluate differences across subgroups for age, education level, gender, race, and original study. The statistical mediation models demonstrated equivalence across subgroups, and this suggests that the models describe mediating mechanisms that are robust across demographic and study-related variables.

The 20 final models, as developed in studies 1 through 5 and further validated by study 6, highlight combinations of Processes of Change and mediators that are most related to smoking

outcomes. Pros, Cons, and Situational Temptations were all found to mediate smoking behavior, with different combinations of processes, for individuals in both PC and C. The most important Processes of Change for individuals in PC included Consciousness Raising, Dramatic Relief, Environmental Reevaluation, Self-Reevaluation, and Social Liberation. The most important Processes of Change for individuals in C included Counter Conditioning, Consciousness Raising, Dramatic Relief, Environmental Reevaluation, Self-Reevaluation, Social Liberation, and Stimulus Control. Only one combination was found to demonstrate statistical mediation for individuals in PR; Self-Reevaluation was found to mediate smoking behavior through Situational Temptations.

Based on the results from the series of statistical mediation analyses, these strategies for smoking behavior change should be emphasized in smoking cessation interventions. Modern interventions can be developed to maximize relevance of intervention contacts and improve effectiveness by tailoring to focus on key behavioral mechanisms. Future interventions can be further refined through new series of statistical mediation analyses.

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PREFACE

This dissertation is comprised of six interrelated manuscripts that represent a comprehensive investigation of the mechanisms of smoking behavior change. Manuscripts 1, 2, and 3 provide an important foundation, and manuscripts 4 and 5 build on the results of these studies. Manuscript 6 builds on all prior manuscripts and helps validate the approach. All of the pages have been formatted in the accepted font and margin requirements. Tables and figures are prefixed with the manuscript number for clarity of labeling across the dissertation. Manuscript format is in use.

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OVERVIEW OF STUDIES

Understanding the mechanisms that underlie behavior change is a basic knowledge that is essential to understanding what drives effective interventions. Historically, many interventions have followed a "black-box" approach, where the intervention components are related to the intervention outcomes, with no empirical investigation of what drives these outcomes. The present series of six studies represents a comprehensive evaluation of the mechanisms of smoking behavior change using statistical mediation analysis. Smoking is the largest preventable cause of disease and death in the United States and represents a critical concern for public health. Better understanding the behavioral mechanisms that help smokers change their behavior will emphasize behavioral strategies to aid quitting smoking and address a major health concern.

Statistical mediation analysis is an advanced methodology that is ideal for investigating and quantifying mechanisms of behavior change. Mediators are intermediate variables that come between independent variables and dependent variables, and they explain the mechanism through which an independent variable influences an outcome. In the context of an intervention designed to change behavior, these mediators are the mechanisms of behavior change. Thus, statistical mediation analysis is utilized to develop empirical models to better understand behavior change mechanisms for smoking.

All studies combine secondary data from five tailored interventions based on the Transtheoretical Model (TTM) for participants in the Precontemplation (PC; N = 1145), Contemplation (C; N = 1243), and Preparation (PR; N = 499) stages at baseline. Each of these intervention trials demonstrated effectiveness for decreasing smoking, and statistical mediation analysis is used to quantitatively deconstruct these interventions and determine which components, and which combinations of components, produced the treatment outcomes. Statistical mediation models under investigation are autoregressive, three-wave models (baseline, 12 months, and 24 months) developed within each stage of change. The ten Processes of Change for Smoking are used as independent variables, Pros of Smoking, Cons of Smoking, and

Situational Temptations to Smoke are used as mediators, and a behavioral smoking outcome is used as the dependent variable. Structural equation modeling (SEM) is utilized to estimate covariance structure, regression paths, error terms, missing data (with maximum likelihood estimation), and assess model fit.

The purpose of study 1 is to investigate single mediator models for individuals in PC at baseline. Individuals in C and PR at baseline are investigated in study 2 and study 3, respectively. For each of these three studies, 30 separate models are investigated (10 Processes of Change * 3 mediators), for a total of 90 statistical mediation models. Model fit, statistical significance of mediation pathways, asymmetric confidence intervals, and effect size measures are considered in the evaluation of the mediated effect.

The purpose of studies 4 and 5 is to refine, consolidate, and extend conclusions from the single mediator models. Combinations of variables that demonstrate evidence of statistical mediation in single mediator models are further combined to develop multiple mediator models (study 4) and models with multiple Processes of Change (study 5). These complex models represent a more comprehensive evaluation of the mechanisms of smoking behavior change. The "final models" represent mediation models that cannot be combined any further.

The purpose of study 6 is to test for the presence of statistical moderation in the final models. Moderator variables influence the direction or degree of association between an independent variable and a dependent variable. Factorial invariance techniques in SEM are utilized to evaluate differences across subgroups for age, education level, gender, race, and original study. Differences across subgroups would suggest the presence of moderation, while equivalence across subgroups would suggest that the mediation models are robust across demographic and study-related variables.

These six studies contribute to increasing basic knowledge of the mechanisms that underlie smoking cessation and to increasing understanding of how these mechanisms relate to successful interventions. Better understanding which behavioral variables are the most important

and most relevant for individuals will directly contribute to future interventions. Modern interventions will be able to adapt to make intervention contacts as relevant as possible by tailoring to individuals to focus on the variables that are most likely to have the biggest effects on behavioral outcomes. These interventions have the potential to be shorter and faster, yet still effective at decreasing smoking, and future interventions can be further refined through new series of statistical mediation analyses.

MANUSCRIPT 1

Investigating the Mechanisms of Smoking Behavior Change:

Single Mediator Models for Smokers in the Precontemplation Stage

Manuscript to be submitted to *Prevention Science*

Abstract

Investigating and quantifying the mechanisms that underlie behavior change is essential to understanding what drives effective interventions. While many population-based smoking interventions have a theoretical framework, the mechanisms that impact behavior change during the intervention are rarely explored empirically. Better understanding variables that explain changes in smoking behavior can provide a basis for more direct and effective interventions. The present study combined data (N = 1145) from five randomized Transtheoretical Model (TTM) - tailored intervention studies. Statistical mediation analysis with autoregressive, three-wave models was utilized to investigate changes in behavioral variables across three time points (baseline, 12 months, and 24 months) for participants in the precontemplation stage (PC; smokers not planning to quit) at baseline. The ten Processes of Change for Smoking were used as independent variables, Pros of Smoking, Cons of Smoking, and Situational Temptations to Smoke were used as mediators, and a behavioral smoking outcome was used as the dependent variable for a total of 30 separate mediation models. Models were assessed with structural equation modeling and all demonstrated very good fit (CFI > 0.95; RMSEA < 0.05). The Pros, Cons, and Situational Temptations all demonstrated evidence of statistical mediation with multiple Processes of Change. Some of the most important Processes of Change for participants in PC at baseline were Consciousness Raising, Dramatic Relief, Environmental Reevaluation, Self-Reevaluation, and Social Liberation. Development and refinement of statistical mediation models to assess the mechanisms of behavior change are crucial to enhancing basic knowledge and informing intervention efforts.

Keywords: Statistical Mediation Analysis, Smoking Cessation, Transtheoretical Model, Precontemplation Stage

Investigating the Mechanisms of Smoking Behavior Change:

Single Mediator Models for Smokers in the Precontemplation Stage

Mechanisms of behavior change explain how and why behavior change occurs. Better understanding behavioral mechanisms necessitates better understanding variables that account for observed changes in behavior. Despite the importance of mechanisms of behavior change, knowledge about these mechanisms is presently very limited. Recent NIH Science of Behavior Change Meeting Reports (2009; 2012) emphasize that the limited knowledge available about the mechanisms of behavior change or the mediators of interventions represents "a fundamental barrier to progress in the science of behavior change" (2009, p. 4). Investigating and quantifying such mechanisms that underlie behavior change is essential to understanding what drives effective interventions. Many interventions follow a "black-box" approach, where the intervention components are related to the intervention outcomes, with no empirical investigation of what drives these outcomes. Many content areas would greatly benefit from a comprehensive investigation of the mechanisms that drive behavior change.

Due to its extreme consequences, cigarette smoking represents a key health behavior that needs to be better understood. Despite decades of prevention and intervention efforts, smoking remains a critical concern for public health in the United States. Approximately 19% of U.S. adults are smokers, and while smoking prevalence rates have decreased from approximately 42% in 1965, this decrease seems to be slowing (Centers for Disease Control [CDC], 2011a; 2011b; 2012). An estimated 443,000 adults die from smoking-related illnesses every year, and smoking is estimated to cost the United States $96 billion and $97 billion in direct medical expenses and lost productivity, respectively (CDC, 2008; 2012). An older estimate suggests that of all the people alive in the world today, 500,000,000 are expected to die from tobacco use (Peto & Lopez, 1990). Given the extreme health and economic costs of smoking, improving interventions to help smokers quit is of paramount importance. Over two-thirds of smokers report that they want to

quit smoking (CDC, 2011c). Better understanding the behavioral mechanisms that help smokers change their behavior will emphasize behavioral strategies to aid quitting smoking and address a major health concern.

The present study combined data from multiple intervention studies that effectively reduced smoking and utilized statistical mediation analysis to examine the mechanisms of smoking behavior change. Statistical mediation analysis is an advanced methodology that is ideal for investigating and quantifying mechanisms of behavior change. These tailored intervention studies were based on a widely-studied model of behavior change, the Transtheoretical Model (TTM).

Statistical Mediation Analysis

In general, mediation models are utilized to investigate how and why two things are related. Intermediate variables that come between independent variables and dependent variables are known as mediating variables, or mediators. A mediator acts as a third variable and represents the mechanism through which an independent variable influences an outcome (Baron & Kenny, 1986). The most basic model (MacKinnon, 2008) involves three key variables: an independent variable, X, a mediating variable, M, and a dependent variable, Y. From this simple model, additional independent variables, mediating variables, time points, and other components can be added to develop increasingly complex mediation models. In the framework of an intervention designed to change behavior, mediators are the mechanisms of behavior change. Thus, statistical mediation analysis was utilized in the present study to develop empirical models to better understand behavior change mechanisms.

A critical feature of the present series of mediation analyses is that all mediation models were longitudinal. Mediation models are also referred to as causal models, as mediators are hypothesized to cause changes in the dependent variables (and not the other way around) (Baron & Kenny, 1986). Thus, developing mediation models that demonstrate change over time requires longitudinal data to study the temporal order of change, as behavior change cannot be assumed to

occur instantly. While mediation analyses can be performed with cross sectional data, such analyses are limited for at least three reasons (Gallob & Reichardt, 1991): (a) time is necessary for variables to have effects on other variables; (b) variables can have effects on themselves over time; and (c) the size of these effects varies over time. Due to its limitations, cross-sectional mediation analyses should be considered both inadequate and inappropriate to study mechanisms of behavior change (Kazdin & Nock, 2003). Longitudinal mediation models require fewer assumptions, provide more accurate descriptions of the temporal order of change, and offer a more comprehensive evaluation of the mechanisms of change (MacKinnon, 2008).

The Transtheoretical Model of Behavior Change

The Transtheoretical Model (TTM) is an integrative framework that consists of multiple dimensions that assess different components of behavior change (Prochaska & Velicer, 1997; Velicer, Prochaska, Fava, Rossi, Redding, Laforge, & Robbins, 2000). Essentially, the TTM represents a model of how individuals adopt healthy behaviors and discontinue unhealthy ones (Brewer & Rimer, 2008). The core constructs of the TTM include stages of change, processes of change, decisional balance, and self-efficacy. Tailored interventions based on the TTM have been empirically validated and have demonstrated effectiveness for a wide variety of behaviors, including smoking (Krebs, Prochaska, & Rossi, 2010; Noar, Benac, & Harris, 2007; Velicer, Prochaska, & Redding, 2006b; Velicer, Redding, Sun, & Prochaska, 2007b). The overall framework of the TTM is ideal for the development of mediation models because it can be conceptually summarized with three dimensions (Velicer et al., 2000): the temporal dimension (stages of change), the independent variable dimension (processes), and the intermediate variable dimension (decisional balance and self-efficacy).

Smoking research and the TTM have a very extensive history. Multiple components of the TTM were empirically refined with smoking as the content area, including stage of change (DiClemente et al., 1991), processes of change (Prochaska & DiClemente, 1983; Prochaska, Velicer, DiClemente, & Fava, 1988), decisional balance (Velicer, DiClemente, Prochaska &

Brandenberg, 1985), and self-efficacy (Velicer, DiClemente, Rossi, & Prochaska, 1990), with longitudinal studies supporting predictive validity in some randomized and some nonrandomized studies (DiClemente et al., 1991; Prochaska, Velicer, Fava, Rossi, & Tsoh, 2001; Prochaska et al., 2004, 2005; Redding et al., 2011; Sun, Prochaska, Velicer, & LaForge, 2007; Velicer et al., 2006b, 2007b). The TTM has been applied to a wide variety of behaviors (e.g., alcohol use, exercise, diet, UV protection, mammography screening), but it has been most widely applied to smoking (Krebs et al., 2010; Noar et al., 2007).

Mechanisms of Behavior Change and Interventions

Data from five TTM-tailored smoking interventions were utilized in the present study, and statistical mediation analysis was used to quantitatively deconstruct these intervention studies and determine which components, and which combinations of components, produced the treatment outcomes. These analyses represent the first time longitudinal mediation models for smoking interventions based on the TTM have been developed. Previous studies have explored potential mediators of smoking interventions with different statistical methods. Of particular relevance to the present study, some past research investigated self-efficacy as a potential mediator of smoking cessation. Some studies have suggested that self-efficacy may function as a mediator of smoking cessation (Cinciripini et al., 2003; Vidrine, Arduino, & Gritz, 2006), while others have found mixed results (Gwaltney, Shiffman, Balabanis, & Paty, 2005; Unger et al., 2000). The present study investigated self-efficacy, as well as pros and cons, as mediators.

Overview of Current Study

Smokers that were identified as being in the precontemplation (PC) stage at the start of intervention were the focus of the present study. This is the first of a series of six studies that utilized statistical mediation analysis to better understand mechanisms of smoking behavior change in TTM-based studies. The second and third studies focused on the contemplation (C) and preparation (PR) stages, respectively. Statistical mediation models were developed within separate stages, as opposed to combining individuals across stages, because differences in stage

have consistently demonstrated nonlinear relations with the other TTM variables (Velicer, Prochaska, Rossi, DiClemente, 1996). The PC stage for smoking cessation includes smokers that are not intending to quit in the next six months. Individuals in this stage are typically not interested in quitting, and avoid strategies to change, such as reading, talking, or thinking about their smoking. Compared to the other stages, precontemplators consistently report the highest Pros of Smoking and the lowest Cons of Smoking; progress towards quitting smoking is typically associated with a decrease in the Pros of Smoking and an increase in the Cons of Smoking (Hall & Rossi, 2008; Velicer et al., 1985).

The goal of the present study was to conduct a comprehensive series of statistical mediation analyses with data from TTM-based intervention studies to identify, for participants that were in the PC stage, which combinations of intervention components demonstrated empirical evidence of mediation. The analytical framework was guided by the TTM, with the ten processes of change acting as independent variables, pros, cons, and self-efficacy acting as mediators, and a smoking behavior outcome acting as the dependent variable. Each of the models only included one mediator, in order to isolate separate intervention components. All models were longitudinal, with data from assessments at three time points (baseline, 12 months, and 24 months). These variables produced a series (10 processes * 3 mediators * 1 outcome) of 30 single mediator models.

Method

Participants

Data from five different smoking intervention studies were combined in the present study. Combining data from multiple large studies was a necessary step to create a sample size large enough to analyze the complex statistical mediation models. These studies could be combined because of a number of crucial similarities. All five studies were large, randomized, clinical trials that were successful in decreasing smoking rates. Each study collected longitudinal data, used representative, population-based sampling, and assessed all key TTM constructs (with

the same items) necessary to run the mediation analyses. Only participants that received the same TTM-based smoking intervention were included in the combined sample; participants in control conditions or participants that received different interventions were not included. Checking the validity of combining these studies by comparing within-study mediation models was included in a separate study (manuscript 6 in the present series of studies). The five separate studies that make up the combined sample were labeled Parent, Patient, Worksite, RDD, and Health. Sample sizes included below represent participants in PC at baseline.

Original Studies. The Parent study (Prochaska et al., 2004) involved parents of students recruited for a school-based study (N=153). In addition to a smoking intervention, participants in this study who were at risk also received interventions on diet and sun exposure. The Patient study (Prochaska et al., 2005) involved patients from an insurance provider list (N=177). In addition to a smoking intervention, participants in this study who were at risk also received interventions on diet, sun exposure, and mammography. The Worksite study (Velicer et al., 2004) involved employees from a sample of worksites (N=77). In addition to a smoking intervention, participants in this study who were at risk also received interventions on diet, sun exposure, and exercise. The RDD study (Prochaska et al., 2001) involved participants from a random digit dial (RDD) sample (N=565). This study intervened only on smoking. The Health study (Velicer, Friedman, Redding, Migneault, & Hoeppner, 2006a; Velicer, Friedman, Redding, Migneault, Hoeppner, & Prochaska, 2007a) involved participants who were smokers and who were at risk for diet and exercise in a multiple risk behavior study (N=173). In addition to a smoking intervention, participants in this study also received interventions on diet and exercise.

Total Combined Sample. The total combined sample for participants in PC at baseline was N = 1145. Participants were 62.6% female and 92.7% white.

Intervention

All participants received a TTM-tailored smoking intervention that assessed key variables at baseline, 12 months, and 24 months. The smoking intervention was a tailored, expert system

intervention, where participants received feedback matched to how they responded to TTM constructs. All interventions began with an assessment of basic demographic variables, smoking variables, and the core measures from the TTM. Interventions provided stage-matched and tailored feedback in a series of three reports at baseline, 3 months, and 6 months (RDD) or at baseline, 6 months, and 12 months (Parent, Patient, Worksite, and Health). Tailoring in these feedback reports involved both highlighting certain strategies to change (processes of change) as well as normative and ipsative comparisons. Data from studies with different intervention schedules were combined because these two different schedules did not produce different results (Velicer et al., 2007b). Participants in all interventions also received multiple follow-up assessments. Additional details involving the expert system intervention are available elsewhere (Velicer & Prochaska, 1999; Velicer et al., 1993).

Measures

Analyses performed in the present study involved all core TTM constructs, including stage of change, processes of change, decisional balance, and self-efficacy. Additional variables, related to smoking behavior, were also used to measure a latent variable for smoking outcome.

Stage of Change. The stages of change represent the temporal dimension of TTM and act as the central organizing framework of the model. Varying levels of readiness to change are represented by five stages: Precontemplation (PC), Contemplation (C), Preparation (PR), Action (A), and Maintenance (M) (DiClemente et al., 1991; Prochaska & DiClemente, 1983). Stages of change for smoking were assessed with algorithms developed to assess intentions to quit smoking (Prochaska & DiClemente, 1983). The PC stage includes participants that report being smokers and report not intending to quit in the next six months.

Processes of Change. The processes of change represent the independent variable dimension of the TTM. The processes involve strategies for changing one's behavior; in TTM-based interventions, the processes play a critical role in tailoring the intervention to the individual. There are ten Processes of Change for Smoking (Prochaska et al., 1988). The ten

processes include experiential processes, which are cognitive and emotional strategies to change behavior, and behavioral processes, which represent more overt changes in behavior. The experiential processes include Consciousness Raising, Dramatic Relief, Environmental Reevaluation, Self-Reevaluation, and Social Liberation. The behavioral processes include Counter Conditioning, Helping relationships, Reinforcement Management, Self Liberation, and Stimulus Control. Detailed descriptions of the Processes of Change for Smoking are available elsewhere (Prochaska et al., 1988). Participants were asked to rate how often they used each process in the last month on a 5-point Likert scale ranging from 1 (Never) to 5 (Repeatedly). Each of the processes was a latent variable measured by two items; details for the items are included in Appendix A. In the total sample, coefficient alphas for the Processes of Change for Smoking scales ranged from 0.60 to 0.84.

Decisional Balance. The decisional balance construct represents part of the intermediate variable dimension of the TTM. Decisional balance, originally adapted from Janis and Mann (1977), assess an individual's weighing of the pros and cons of engaging in a behavior. The relationship between decisional balance and the stages of change has been replicated across more than 48 different health behaviors (Hall & Rossi, 2008). The Decisional Balance Scale for Smoking is a six-item scale with three items for the Pros of Smoking and three items for the Cons of Smoking (Velicer et al., 1985). These items assess the relative importance of the pros and cons of smoking. Participants were asked to rate the importance of each item on a 5-point Likert scale ranging from 1 (Not important) to 5 (Extremely important). The Pros of Smoking and the Cons of Smoking were represented by latent variables, each measured by three items; details for the items are included in Appendix A. In the total sample, coefficient alpha was 0.70 for the Pros of Smoking and 0.66 for the Cons of Smoking.

Self-Efficacy. The self-efficacy construct represents the other part of the intermediate variable dimension of the TTM. Originally adapted from Bandura (1977), the self-efficacy construct assesses an individual's perceived ability to perform behaviors in difficult situations.

Self-efficacy increases as one transitions TTM stages (Velicer et al., 1990). Improved self-efficacy predicts improved outcomes; this relationship has been repeatedly demonstrated for smoking (Blissmer et al., 2010; Prochaska, DiClemente, Velicer, Ginpil, & Norcross, 1985; Prochaska, Velicer, DiClemente, Guadagnoli, & Rossi, 1991). In the framework of the TTM, self-efficacy either describes the confidence to engage in a healthy behavior or describes temptations to engage in an unhealthy behavior. For smoking, self-efficacy is measured by the Situational Temptations to Smoke scale (Velicer et al., 1990). The Situational Temptations describe situations that may lead some people to smoke. The instrument is a nine-item scale with three items for positive affect / social situations, three items for negative affect situations, and three items for habitual / craving situations. Participants were asked to rate how tempted to smoke they felt on a 5-point Likert scale ranging from 1 (Not at all tempted) to 5 (Extremely tempted). Details for the items are included in Appendix A. In the present study, averages of these three item content areas (e.g., positive affect / social situations) were calculated to represent Situational Temptations for Smoking with three items; a latent variable for Situational Temptations was measured by these three items. Coefficient alpha for this three-item scale was 0.78 in the total sample.

Smoking Outcome. The smoking behavioral outcome was a latent variable measured by two key items from the widely-used Fagerstrom Test for Nicotine Dependence (FTND; Fagerstrom, 1978), time to first cigarette and number of cigarettes smoked per day. These two continuous variables were converted to 5-point scales, with higher values indicating more smoking. This step was performed for three reasons: to better represent nonsmokers; to better reflect the point-based system of the FTND; and to create consistency with the other items (processes, pros, cons, situational temptations), which are all on 5-point scales. Details for the items are included in Appendix A. Coefficient alpha for this measure was 0.75 in the total sample.

Statistical Analysis

Development of the series of 30 single mediator models can be summarized by two phases of analysis. The first phase involved the creation of models that best fit the data. The second phase involved the assessment of paths within the models to search for evidence of statistical mediation.

Creation and Fit Assessment of Mediation Models. Developing models that fit the data is essential to establishing a framework for statistical mediation. Creation of the single-mediator models was guided by the hypothesized TTM framework, where processes are the independent variables (X), decisional balance (pros, cons) and self-efficacy are mediators (M), and the smoking outcome is the dependent variable (Y). In the present study, only participants that were PC at baseline were included. This set of variables (10 processes * 3 mediators * 1 outcome) produced a total of 30 single-mediator models.

All of the mediation models in the present study were latent variable models. The use of latent variables improves the reliability of the measures (MacKinnon, 2008). Data were available at baseline, 12 months, and 24 months, and therefore all mediation models were longitudinal, three-wave models. These models represent autoregressive mediation models (Cole & Maxwell, 2003; Gallob & Reichardt, 1991, MacKinnon, 2008). In longitudinal, autoregressive, three-wave mediation models, each variable is predicted by the same variable at an earlier wave. Due to the number of parameters being estimated in each model, and the use of latent variables, structural equation modeling (SEM) was an ideal analytic tool to assess these mediation models (Iacobucci, Saldanha, & Deng, 2007; MacKinnon, 2008).

SEM was utilized to analyze the covariance structure, estimate regression paths, estimate error terms, and assess model fit. Missing data, which are extremely common in longitudinal studies, were also estimated with maximum likelihood (ML) procedures. Using ML methods in SEM has been demonstrated to be accurate and less biased than conventional methods such as listwise or pairwise deletion (Allison, 2003; Enders & Bandalos, 2001). The following commonly-used indices were used as benchmarks to assess the model fit: likelihood ratio chi-

square ($\chi 2$), Normed Fit Index (NFI), Comparative Fit Index (CFI), and Root Mean Squared Error of Approximation (RMSEA). Likelihood ratio chi-square provides a test for fit of the model based on the chi-squared distribution. The chi-square test is extremely sensitive to large sample sizes (Kline, 2005) and will always reject models with large sample sizes. Due to this issue, and the large sample sizes in the present study, chi-square values are reported but results for its associated significance test are not. For NFI and CFI, values greater than 0.90 indicate good fit and values greater than 0.95 indicate very good fit (Bentler & Bonnet, 1980; Kline, 2005). For RMSEA, values less than 0.10 indicate good fit and values less than 0.05 indicate very good fit (Browne & Cudeck, 1993). An important goal of creating longitudinal mediation models in SEM was to find a model that fit well across all 30 single mediator combinations. A common underlying model created the opportunity to compare results across the 30 single mediator models.

Assessing Statistical Mediation. While model fit is crucial to the validity of the analyses, evaluating the regression paths is arguably more important to the overall procedure, as this step determines which combinations of variables actually demonstrate empirical evidence of statistical mediation. Analysis with SEM includes the estimation of regression paths among the variables. In three-wave autoregressive mediation models, two paths are particularly important to mediation: X at time 1 to M at time 2 (path a_1) and M at time 2 to Y at time 3 (path b_2). Together, these two paths represent the mediation pathway, which is also known as the indirect effect or the intervening effect (MacKinnon, Lockwood, & Williams, 2004; Preacher & Hayes, 2008; Sobel, 1982). Statistical significance of each of these paths was assessed separately in SEM; if each path demonstrated statistical significance, this finding suggests that the mediation pathway may be significant. To further assess for evidence of mediation, asymmetric confidence intervals for the product of these paths were calculated (MacKinnon, 2008; Tofighi & MacKinnon, 2011). If the confidence interval did not include zero, there was evidence of statistical mediation.

There is no consensus on what estimates best represent effect sizes for statistical mediation analysis, and this topic represents an area that is currently under refinement (Fairchild, MacKinnon, Taborga, & Taylor, 2009; Preacher & Kelly, 2011; MacKinnon, 2008). In the present study, standardized coefficients for a_1 and b_1 were reported, as well as the product of the standardized coefficients (MacKinnon, 2008). These estimates help describe the magnitude of the mediated effect and will be interpreted similarly to R^2, where product absolute values of 0.01, 0.06, and 0.13 correspond to small, medium, and large effect sizes (Cohen, 1992).

Results

Creation and Fit Assessment of Mediation Models

As a first step, descriptive analyses were performed on the combined dataset (N = 1145) to check for extreme skewness and kurtosis values for the study variables (West, Finch, & Curran, 1995). All skewness variables and kurtosis values were between -2 and 2. Basic descriptive statistics for the averages of study variables (means and standard deviations) are included in Table 1.1.

SEM was employed with EQS 6.1 software (Bentler, 2007) to develop the single mediator models. Suggestions from Cole and Maxwell (2003) and MacKinnon (2008) were utilized to create a variety of autoregressive mediation models, including a basic autoregressive mediation model (autoregressive mediation model I), a more advanced model (autoregressive mediation model II), and a fully cross-lagged model. Fit statistics across these sample models consistently suggested that an autoregressive model II best fit the data. The template for the autoregressive mediation model II is included in Figure 1.1. There are six key characteristics to the autoregressive mediation model II (MacKinnon, 2008). First, relations are modeled one lag apart (e.g., 12 months to 24 months). Second, relations between the same variables over time are modeled to assess stability (the *s* coefficients). Third, the model includes regression paths that describe longitudinal mediation (e.g., independent variable at time 1 to mediator at time 2, independent variable at time 1 to dependent variable at time 2). Fourth, covariances among the

variables at the first wave are estimated. Fifth, covariances among error terms are estimated at each wave. Sixth, relations between the independent variable and mediator, as well as mediator and dependent variable, are modeled. This is called contemporaneous mediation; the purpose of these paths is to help account for change that occurs between the time points. With the autoregressive model II framework selected, all 30 single mediator models were created.

Model Fit Statistics. The series of 30 mediation models (10 processes * 3 mediators * 1 outcome) were successfully created. First, the models were conducted using complete cases only. Fit statistics from the complete case analysis are included in Table 1.2. With Pros of Smoking and Cons of Smoking as mediators, all models demonstrated a very good fit, with CFI values consistently above 0.95 and RMSEA values consistently below 0.05. With Situational Temptations as mediator, all models demonstrated very good CFI values and slightly higher RMSEA values, with CFI values consistently above 0.95 and RMSEA values consistently below 0.06.

Second, due to the large number of participants that had missing data on one or more of the variables (over 50% of the sample), the models were conducted using ML to estimate missing data. Fit statistics from the ML models are included in Table 1.3. The conclusions from these fit statistics matched the complete case analysis, with all models demonstrating exceptional fit.

Assessing Statistical Mediation

To assess the models for evidence of statistical mediation, the longitudinal regression paths estimated in SEM were evaluated. The mediation pathway (process at baseline to mediator at 12-months, a_1, and mediator at 12-months to outcome at 24-months, b_2) within each model was assessed in two steps. First, the statistical significance of each path (a_1 and b_2 in Figure 1.1) was assessed. Second, the RMediation (Tofighi & MacKinnon, 2011) application was employed to estimate asymmetric confidence intervals for the product of these paths. Models estimated with complete case analysis and models estimated with ML for missing data were assessed for evidence of statistical mediation. In all cases, the conclusions from both sets of models were

equivalent. Results from models that included missing data estimation with ML are reported, as these estimates are less biased (Allison, 2003; Enders & Bandalos, 2001). Diagrams are included for models where the mediation pathway demonstrated a medium or greater effect size.

Statistical Mediation with Pros of Smoking as Mediator. Unstandardized and standardized longitudinal regression paths describing the mediation pathway through the Pros of Smoking are included in Table 1.4. Four processes demonstrated statistical significance for both components of the mediation pathway. These processes, with standardized regression paths, were: Consciousness Raising (std. a_1 = -0.256, std. b_2 = -0.411); Dramatic Relief (std. a_1 = -0.144, std. b_2 = -0.418); Self-Reevaluation (std. a_1 = -0.177, std. b_2 = -0.460); and Social Liberation (std. a_1 = -0.243, std. b_2 = -0.445).

Products, asymmetric confidence intervals, and products of standardized coefficients are included in Table 1.5. All four of the previously identified processes had confidence intervals that did not include zero: Consciousness Raising (0.038, 0.326; std. product = 0.105, medium-large effect; Figure 1.2); Dramatic Relief (0.003, 0.209; std. product = 0.060, medium effect; Figure 1.3); Self-Reevaluation (0.030, 0.254; std. product = 0.081, medium effect; Figure 1.4); and Social Liberation (0.042, 0.328; std. product = 0.108, medium-large effect; Figure 1.5). These four Processes of Change for Smoking demonstrated evidence of statistical mediation with the Pros of Smoking as a mediator.

Statistical Mediation with Cons of Smoking as Mediator. Unstandardized and standardized longitudinal regression paths describing the mediation pathway through the Cons of Smoking are included in Table 1.4. Six processes demonstrated statistical significance for both components of the mediation pathway. These processes, with standardized regression paths, were: Dramatic Relief (std. a_1 = -0.222, std. b_2 = -0.167); Environmental Reevaluation (std. a_1 = -0.188, std. b_2 = -0.237); Self-Reevaluation (std. a_1 = -0.403, std. b_2 = -0.222); Social Liberation (std. a_1 = -0.477, std. b_2 = -0.273); Helping Relationships (std. a_1 = -0.125, std. b_2 = -0.269); and Self Liberation (std. a_1 = -0.213, std. b_2 = -0.190).

Products, asymmetric confidence intervals, and products of standardized coefficients are included in Table 1.5. Five out of the six previously identified processes had confidence intervals that did not include zero: Environmental Reevaluation (0.009, 0.134; std. product = 0.045, small-medium effect); Self-Reevaluation (0.006, 0.298; std. product = 0.089, medium effect; Figure 1.6); Social Liberation (0.048, 0.355; std. product = 0.130, large effect; Figure 1.7); Helping Relationships (0.002, 0.106; std. product = 0.034, small effect); and Self Liberation (0.006, 0.124; std. product = 0.040, small-medium effect). These five Processes of Change for Smoking demonstrated evidence of statistical mediation with the Cons of Smoking as a mediator. Dramatic relief (-0.003, 0.136; std. product = 0.037) had a confidence interval that included zero, which suggests this process did not demonstrate meaningful evidence of statistical mediation through the Cons of Smoking.

Statistical Mediation with Situational Temptations as Mediator. Unstandardized and standardized longitudinal regression paths describing the mediation pathway through the Situational Temptations to Smoke are included in Table 1.4. Three processes demonstrated statistical significance for both components of the mediation pathway. These processes, with standardized regression paths, were: Consciousness Raising (std. a_1 = -0.275, std. b_2 = -0.317); Dramatic Relief (std. a_1 = -0.111, std. b_2 = -0.305); and Environmental Reevaluation (std. a_1 = -0.100, std. b_2 = -0.334).

Products, confidence intervals, and products of standardized coefficients are included in Table 1.5. All three of the previously identified processes had confidence intervals that did not include zero: Consciousness Raising (0.046, 0.337; std. product = 0.087, medium effect; Figure 1.8); Dramatic Relief (0.003, 0.153; std. product = 0.034, small effect); and Environmental Reevaluation (0.004, 0.144; std. product = 0.033, small effect). These three Processes of Change for Smoking demonstrated evidence of statistical mediation with Situational Temptations as a mediator.

Discussion

Advanced statistical mediation analysis techniques were utilized to investigate variables hypothesized to underlie changes in smoking behavior. A series of 30 single mediator models for participants in the PC stage for smoking at baseline was successfully conducted. Smokers in the PC stage reported no intentions to quit smoking in the next six months. All models utilized the framework of an autoregressive mediation model II (MacKinnon, 2008), had three time points (baseline, 12 months, and 24 months), and employed SEM to estimate covariance structure, regression paths, error terms, missing data with ML, and assess model fit. All models demonstrated a great fit, and a total of 12 combinations of processes and mediators demonstrated evidence of statistical mediation.

Models with the Pros of Smoking as Mediator

The Pros of Smoking represent positive or appealing aspects of cigarette smoking and their importance to the smoker (Velicer et al., 1985). The Pros were hypothesized as a potential mediator because of empirical evidence that the Pros of Smoking typically decrease as a smoker makes progress towards quitting smoking (Hall & Rossi, 2008). For participants starting an intervention in the PC stage, four Processes of Change for Smoking were found to demonstrate evidence of statistical mediation through the Pros of Smoking. They were Consciousness Raising, Dramatic Relief, Self-Reevaluation, and Social Liberation. Evidence from significance tests of regression paths and asymmetric confidence intervals suggest that each of these processes influenced the Pros, which in turn influenced the smoking outcome.

The Processes of Change for Smoking have a correlated higher-order factor structure with two dimensions: experiential processes and behavioral processes (Prochaska et al., 1988). The experiential processes involve cognitive and emotional strategies to change behavior, and are typically most important to smokers in PC (Prochaska, DiClemente, & Norcross, 1992). The four Processes of Change for Smoking that were found to impact smoking outcome through the Pros

of Smoking were all experiential processes. This finding provides longitudinal evidence supporting the validity of this TTM prediction.

Models with the Cons of Smoking as Mediator

The Cons of Smoking represent negative or unappealing aspects of cigarette smoking and their importance to the smoker (Velicer et al., 1985). The Cons were hypothesized as a potential mediator because of empirical evidence that the Cons of Smoking typically increase as a smoker makes progress to quitting smoking (Hall & Rossi, 2008). For participants starting an intervention in the PC stage, five Processes of Change for Smoking were found to demonstrate evidence of statistical mediation through the Cons of Smoking. They were Environmental Reevaluation, Self-Reevaluation, Social Liberation, Helping Relationships, and Self Liberation.

For the Pros of Smoking, all four processes associated with evidence of statistical mediation were experiential processes. For the Cons of Smoking, three out of five (Environmental Reevaluation, Self-Reevaluation, and Social Liberation) were experiential processes, which provides support for the TTM prediction that experiential processes are the most important to individuals in PC. However, two out of the five (Helping Relationships and Self Liberation) processes that demonstrated statistical mediation through the Cons were behavioral processes. This finding suggests that individuals in PC, who have minimal interest in quitting, receive some benefit from interventions that target more overt behaviors, such as receiving support from friends (Helping Relationships).

Models with Situational Temptations as Mediator

Situational Temptations to Smoke assess situations where smokers would feel tempted to smoke (Velicer et al., 1990). Situational Temptations were hypothesized as a potential mediator because of evidence that temptations typically decrease as a smoker makes progress towards quitting smoking (Blissmer et al., 2010; Prochaska et al., 1985; Prochaska et al., 1991). For participants starting an intervention in the PC stage, three Processes of Change for Smoking were found to demonstrate evidence of statistical mediation through the Situational Temptations to

Smoke. They were Consciousness Raising, Dramatic Relief, and Environmental Reevaluation. Like with the Pros of Smoking, all of the processes that demonstrated evidence of mediation through Situational Temptations to Smoke were experiential processes. This finding further supports the TTM hypothesis that experiential processes are extremely valuable to smokers in PC.

Overall Patterns

All five separate studies that were combined to create the sample for the present study were successful in decreasing smoking rates. By breaking apart the intervention components and investigating statistical mediation over time, these studies have essentially undergone a quantitative dissection to reveal what intervention components drove the outcomes. The Pros of Smoking, Cons of Smoking, and Situational Temptations to Smoke all demonstrated evidence of statistical mediation with multiple Processes of Change for Smoking. The combinations of variables that demonstrated statistical mediation provide valuable insight into what drove the smoking outcomes.

Different combinations of independent variables and mediators produced mediation effects of different magnitudes. Effect sizes quantify the strength of the mediational relations and are pivotal to interpreting the overall evidence for mediation. Four Processes of Change for Smoking demonstrated medium or large mediation effects, based on standardized paths (product of standardized paths ≥ 0.06 for medium, ≥ 0.13 for large). These four processes, from largest to smallest effects, were: Social Liberation, Consciousness Raising, Self-Reevaluation, and Dramatic Relief. Social Liberation involves observing how social changes are benefitting nonsmokers. Increasing cognitive awareness of how society is changing is important to driving change in smoking behavior. Consciousness Raising involves thinking about quitting smoking and the benefits of quitting smoking. At PC, increasing Consciousness Raising should be considered a priority, as many in this stage are not thinking about their smoking. Self-Reevaluation involves individuals feeling upset or disappointed with themselves for smoking, and Dramatic Relief involves feeling emotionally moved by warnings about the consequences of

smoking. Results from the present study suggest that negative emotions such as fear and disappointment are important to changing smoking attitudes and intentions early in the change process.

In addition to evaluating the magnitude of the mediated effects, the Processes of Change that demonstrated mediation through multiple mediators also should be considered important. These processes included Consciousness Raising (pros and temptations), Dramatic Relief (pros and temptations), Environmental Reevaluation (cons and temptations), Social Liberation (pros and cons), and Self-Reevaluation (pros and cons). All of these processes, except for Environmental Reevaluation, were already identified as being important based on their effect sizes. Environmental Reevaluation involves thinking about both the polluting effects of smoking and the impact on the smokers' social environment. Thus, the consideration of how smoking impacts others, as well as the environment, is important to influencing smoking behavior. Helping Relationships and Self Liberation also demonstrated evidence of statistical mediation, but they demonstrated small effects through only one mediator.

The two paths that made up the mediation pathway, process at baseline to mediator at 12 months (a_1) and mediator at 12 months to smoking outcome at 24 months (b_2), were the focus of the present study, but there were many other paths that revealed important information about statistical mediation. Two additional paths that were important to mediation were the two direct effects, process at baseline to smoking outcome at 12 months (c'_1) and process at 12 months to smoking outcome at 24 months (c'_2). These paths describe the relations from the independent variables to the dependent variables, adjusted for the effects of the mediators. In statistical mediation models, effective mediators should result in comparatively small direct effects, and in the present study, the direct effects were consistently very small. The path from mediator at baseline to smoking outcome at 12 months (b_1) also described important patterns. In general, the magnitude of the b_1 path was smaller than the magnitude of the b_2 path. This pattern provides

evidence of an intervention effect; the relation between the mediator and the outcome consistently increased over time. Examples of these relations are included in Figures 1.2 through 1.8.

Limitations

The use of secondary data represents the biggest limitation to the present study. Limitations from the original studies impacted the statistical mediation analyses in a number of ways. First, the diversity of the sample was suboptimal; each of the five studies was primarily white, and the combined sample was nearly 93% white. A substantially more diverse sample, with more participants of different races and different ethnicities, would greatly improve the validity of these statistical mediation models. Additionally, a truly international sample would further increase the generalizability of the results, and the results would better represent the true underlying mechanisms of smoking behavior change.

Second, the details of the tailored interventions produced some limitations. The five original studies that comprised the combined sample all utilized stage-matched tailoring; participants in different stages received feedback that emphasized certain processes of change. For example, participants in PC typically received feedback that highlighted experiential processes of change, such as Consciousness Raising, Environmental Reevaluation, and Self-Reevaluation. Since participants did not receive an equal amount of feedback for each of the ten processes, the tailoring may have impacted process use differentially. Determining the extent to which the tailoring influenced the relations among the processes and the mediators was impossible because control groups could not be included in the analyses. All analyses were conducted on participants that were in treatment groups, and the lack of control groups created multiple important limitations. Analyses could not be performed because the processes of change were not assessed in the control conditions of the original studies (to reduce contamination due to measurement). Comparisons among the treatment and control groups would have revealed important intervention effects as well as additional insight into the mechanisms of smoking behavior change. If the mediation relations described in the present study truly represent

mechanisms of behavior change for smoking, control groups would demonstrate similar relations, but with lower magnitudes, as TTM interventions are thought to accelerate naturalistic processes of behavior change (Prochaska & Velicer, 1997; Velicer et al., 2000; Velicer et al., 2006b). Additionally, evidence for causality was limited due to the lack of data from control groups; comparing data from randomized treatment and control conditions would greatly enhance evidence of causal relations.

Third, measurement issues from the original studies resulted in some limitations. The lack of data for the processes of change in control groups, as discussed above, was the biggest limitation. Another limitation was that the short forms of all measures were utilized. For example, each of the processes of change was measured by two items. In the intervention studies, this was necessary to prevent the assessments from being unreasonably long. For the present study, measures with more items would have been very beneficial. Coefficient alpha values for many measures, including the processes of change, pros, and cons were often low (but still within an acceptable range); internal consistency for each measure would be improved with additional items. Additional items for measures may have also improved the predictive power of constructs. Relations among processes of change and mediators, as well as processes of change and smoking outcomes, were typically smaller in magnitude than the relations among mediators and smoking outcomes. This finding may be partially explained by the two-item scales for the processes. Additional items for each of the processes could increase the magnitude of relations, and this could result in more evidence for statistical mediation.

Smoking outcome was an important component of all mediation models and was associated with some limitations. Unlike other constructs in the present study (e.g., Consciousness Raising, Cons of Smoking), which were previously validated in past studies, the smoking outcome was specifically developed to perform statistical mediation models for smoking. The two items that measured the latent variable for smoking outcome, time to first cigarette and cigarettes per day, have been used extremely often in smoking intervention studies,

but are typically not combined as a latent variable. Thus, the measure could benefit from more vigorous psychometric testing in the future. As with the other scales, the smoking outcome would be strengthened by additional items. One type of item that would be particularly beneficial for the smoking outcome would be an item that reflected stage progression. The present smoking outcome may not have fully captured subtle changes for participants in PC due to the content of the items (time to first cigarette, cigarettes per day). Someone in PC may not change on these overt behaviors, but may progress to C, which predicts future change (Blissmer et al., 2010). Regardless, the smoking outcome variable in the present study performed very well, and correlated highly with Situational Temptations to Smoke, which has been used in the past as a smoking outcome variable (Velicer et al., 1996).

Fourth, timing issues related to both measurement and intervention were also limitations. At least three time points were necessary to run the longitudinal mediation models; baseline, 12 months, and 24 months were selected because all original five studies had full assessments at these time points. However, in all of these studies the intervention was complete by the 12-month time point. Thus, the most dramatic changes may have occurred between baseline and 12 months, but these could not be fully captured in the mediation models. The changes from 12 months to 24 months involved the lasting effects of the intervention. The mediation models in the present study described changes over a wide time frame, and they would be improved with additional time points.

All of these areas of limitations could be addressed with a study specifically designed to test mediational hypotheses. An ideal TTM-tailored intervention study to test mediation would (1) recruit a large, diverse sample; (2) collect data for all TTM constructs for both treatment and control groups; (3) utilize scales for TTM constructs that had more than two items each and include extra items to assess smoking behavior; and (4) perform full assessments (at least) every six months. With the data produced by such a study, the resulting mediation models would provide very compelling evidence of the mechanisms of smoking behavior change.

An important limitation of the present study, likely unrelated to the use of secondary data, involved the signs of the regression paths in the mediation models. In many instances, the signs of regression paths were opposite from what was expected. The longitudinal regression paths in particular had some unusual patterns. Notably, the path from the mediator at 12 months to the smoking outcome at 24 months (b_2) in the mediation pathway was consistently found to be negative. This negative path is challenging to interpret. For example, consider the Pros of Smoking; a negative b_2 coefficient would suggest that a decrease in the Pros of Smoking at 12 months predicts an increase in smoking at 24 months, which is incorrect. In fact, the Pros of Smoking at 12 months were positively, not negatively, correlated with the smoking outcome at 24 months. This unexpected finding suggests the presence of suppressor effects (Kline, 2005; MacKinnon, 2008; Velicer, 1978). Suppressor effects are common in longitudinal structural equation models and are even more common when latent variables are involved (Maassen & Bakker, 2001).

The unexpectedly negative b_2 paths likely represent examples of negative suppression, where the signs are reversed due to the presence of other, stronger positive predictors of smoking outcome at 24 months. For the b_2 path from the Pros of Smoking at 12 months to smoking at 24 months, these other predictors included smoking outcome at 12 months and the Pros of Smoking at 24 months. Further evidence of suppression was found through modification of the models. When one of the strong predictors of smoking outcome at 24 months was deleted from the model (either the smoking outcome at 12 months or the Pros of Smoking at 24 months), the sign of the longitudinal mediation path b_2 flipped from negative to positive. This suggested that b_2 was negative simply because of the other predictors. Due to suppression effects, the signs of regression paths need to be interpreted with caution. Instead, effect sizes should be the emphasis of interpretation. The magnitude of each regression path, as described by the standardized coefficients, is very important. The effect size of the overall mediation pathway, calculated from

the product of the standardized coefficients, is also more important to describing mediation than the signs of any individual paths.

Future Directions for Analysis

As described above, some of the processes showed mediation through multiple mediators. These combinations can be investigated with multiple mediator models. In addition to multiple mediator models, nearly 20 separate pairs of processes showed mediation through the same mediator, and these multiple process models can also be investigated. Separate studies (manuscripts 4 and 5 in the present series of studies) will evaluate both multiple mediator and multiple process models. Creating models with additional independent and mediator variables will provide a more comprehensive investigation of what is driving the intervention outcomes.

An important validity check for the statistical mediation models developed in the present study will be whether the estimates are consistent across subsamples. For example, different age groups may demonstrate different patterns within the single mediator models. In the framework of SEM, multiple subsamples can be compared simultaneously with factorial invariance procedures (Meredith, 1993). A separate study (manuscript 6 in the present series of studies) will evaluate factorial invariance across a series of subgroup variables, including age, education level, gender, race, and original study.

Conclusions

For participants at PC, the Pros of Smoking, Cons of Smoking, and Situational Temptations were found to be important mediators for smoking behavior. Consciousness Raising, Dramatic Relief, Environmental Reevaluation, Self-Reevaluation, and Social Liberation were crucial for driving changes in these mediators. Increasing basic knowledge of the mechanisms that underlie smoking cessation directly relates to increasing understanding of how these mechanisms relate to successful interventions. Modern, computerized interventions can adapt to make intervention contacts as relevant as possible by tailoring to individuals to focus on which behavioral mechanisms are the most important to changing behavior. Thus, future improvement

and refinement of statistical mediation models will directly lead to improvement and refinement of smoking cessation interventions, and development of more effective interventions for smoking will address a major concern for public health.

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Table 1.1. Average means with standard deviations for participants at PC at baseline for independent variables (ten Processes of Change for Smoking Cessation), mediators (Pros, Cons, Situational Temptations), and dependent variables (smoking outcome) at the baseline, 12-month, and 24-month time points

Variable	Baseline		12 Months		24 Months	
	Mean	SD	Mean	SD	Mean	SD
Independent Variables						
Experiential processes						
Consciousness Raising	2.637	1.019	2.592	1.011	2.608	1.048
Dramatic Relief	2.145	1.021	2.342	1.038	2.410	1.115
Environmental Reevaluation	2.451	1.226	2.390	1.141	2.527	1.216
Self-Reevaluation	2.256	1.144	2.537	1.195	2.530	1.201
Social Liberation	3.771	1.095	3.828	1.024	4.006	1.020
Behavioral Processes						
Counter Conditioning	2.125	0.891	2.302	0.933	2.320	0.979
Helping Relationships	2.239	1.285	2.409	1.286	2.521	1.295
Reinforcement Management	1.823	1.087	1.956	1.081	2.138	1.181
Self Liberation	2.482	1.172	2.700	1.161	2.818	1.243
Stimulus Control	1.315	0.661	1.514	0.834	1.625	0.894
Mediators						
Pros	2.544	1.012	2.443	1.017	2.493	1.045
Cons	2.855	0.988	2.868	1.081	2.956	1.117
Situational Temptations	3.387	0.803	3.267	0.936	3.156	1.055
Dependent Variables						
Smoking Outcome	3.429	0.826	3.189	1.049	3.083	1.174

All variables on a 1-5 scale; see appendix for additional materials on the scales

Table 1.2. Fit indices at PC for all mediation models, complete case analysis

Model	N	χ^2	(df)	NFI	CFI	RMSEA	(90% RMSEA)
Mediator: Pros of Smoking							
Consciousness Raising	433	203.693	(149)	0.942	0.962	0.029	(0.018, 0.039)
Dramatic Relief	431	201.197	(149)	0.949	0.986	0.029	(0.017, 0.038)
Environmental Reevaluation	432	227.058	(149)	0.948	0.982	0.034	(0.025, 0.043)
Self-Reevaluation	432	255.572	(149)	0.938	0.982	0.041	(0.032, 0.049)
Social Liberation	432	191.890	(149)	0.945	0.987	0.026	(0.013, 0.036)
Counter Conditioning	432	276.230	(149)	0.921	0.962	0.044	(0.036, 0.052)
Helping Relationships	428	222.515	(149)	0.946	0.981	0.034	(0.024, 0.043)
Reinforcement Management	431	201.269	(149)	0.950	0.986	0.029	(0.017, 0.038)
Self Liberation	433	237.116	(149)	0.938	0.976	0.037	(0.028, 0.046)
Stimulus Control	433	220.864	(149)	0.940	0.980	0.033	(0.023, 0.042)
Mediator: Cons of Smoking							
Consciousness Raising	428	203.535	(149)	0.938	0.982	0.029	(0.018, 0.039)
Dramatic Relief	426	220.517	(149)	0.941	0.980	0.034	(0.024, 0.043)
Environmental Reevaluation	427	231.846	(149)	0.944	0.979	0.036	(0.027, 0.045)
Self-Reevaluation	427	232.008	(149)	0.942	0.978	0.036	(0.027, 0.045)
Social Liberation	427	161.638	(149)	0.949	0.996	0.014	(0.000, 0.027)
Counter Conditioning	427	235.902	(149)	0.924	0.970	0.037	(0.028, 0.046)
Helping Relationships	423	217.159	(149)	0.943	0.981	0.033	(0.023, 0.042)
Reinforcement Management	426	201.339	(149)	0.946	0.985	0.029	(0.017, 0.038)
Self Liberation	428	251.793	(149)	0.930	0.970	0.040	(0.031, 0.048)
Stimulus Control	428	240.572	(149)	0.928	0.971	0.038	(0.029, 0.046)
Mediator: Situational Temptations							
Consciousness Raising	435	322.130	(149)	0.936	0.964	0.052	(0.044, 0.059)
Dramatic Relief	433	295.385	(149)	0.946	0.972	0.048	(0.040, 0.056)
Environmental Reevaluation	434	311.769	(149)	0.947	0.972	0.050	(0.042, 0.057)
Self-Reevaluation	434	334.950	(149)	0.940	0.966	0.054	(0.046, 0.061)
Social Liberation	434	309.142	(149)	0.939	0.953	0.050	(0.042, 0.058)
Counter Conditioning	434	357.363	(149)	0.929	0.957	0.057	(0.049, 0.064)
Helping Relationships	430	305.869	(149)	0.946	0.971	0.050	(0.042, 0.057)
Reinforcement Management	433	316.722	(149)	0.943	0.969	0.050	(0.043, 0.058)
Self Liberation	435	311.136	(149)	0.942	0.968	0.050	(0.042, 0.058)
Stimulus Control	435	289.786	(149)	0.944	0.972	0.047	(0.039, 0.055)

Table 1.3. Fit indices at PC for all mediation models, missing data estimated with ML

Model	N	χ^2	(df)	NFI	CFI	RMSEA	(90% RMSEA)
Mediator: Pros of Smoking							
Consciousness Raising	1145	200.452	(149)	0.999	1.000	0.000	-
Dramatic Relief	1145	209.755	(149)	0.999	1.000	0.000	-
Environmental Reevaluation	1145	252.830	(149)	1.000	1.000	0.000	-
Self-Reevaluation	1145	272.068	(149)	0.998	1.000	0.000	-
Social Liberation	1145	188.497	(149)	1.000	1.000	0.000	-
Counter Conditioning	1145	356.152	(149)	0.974	1.000	0.000	(0.000, 0.007)
Helping Relationships	1145	233.000	(149)	1.000	1.000	0.000	-
Reinforcement Management	1145	217.848	(149)	0.995	1.000	0.000	-
Self Liberation	1145	251.755	(149)	0.997	1.000	0.000	-
Stimulus Control	1145	242.124	(149)	0.995	1.000	0.000	-
Mediator: Cons of Smoking							
Consciousness Raising	1145	209.028	(149)	0.999	1.000	0.000	-
Dramatic Relief	1145	242.608	(149)	1.000	1.000	0.000	-
Environmental Reevaluation	1145	240.769	(149)	1.000	1.000	0.000	-
Self-Reevaluation	1145	258.250	(149)	0.998	1.000	0.000	-
Social Liberation	1145	165.337	(149)	1.000	1.000	0.000	-
Counter Conditioning	1145	282.987	(149)	0.999	1.000	0.000	-
Helping Relationships	1145	221.172	(149)	1.000	1.000	0.000	-
Reinforcement Management	1145	230.274	(149)	0.997	1.000	0.000	-
Self Liberation	1145	257.296	(149)	0.997	1.000	0.000	-
Stimulus Control	1145	272.538	(149)	0.998	1.000	0.000	-
Mediator: Situational Temptations							
Consciousness Raising	1145	412.843	(149)	0.990	1.000	0.000	-
Dramatic Relief	1145	400.204	(149)	0.989	1.000	0.000	-
Environmental Reevaluation	1145	421.272	(149)	0.993	1.000	0.000	-
Self-Reevaluation	1145	439.994	(149)	0.991	1.000	0.000	-
Social Liberation	1145	416.404	(149)	0.989	1.000	0.000	-
Counter Conditioning	1145	510.749	(149)	0.970	0.990	0.021	(0.015, 0.026)
Helping Relationships	1145	403.245	(149)	0.993	1.000	0.000	-
Reinforcement Management	1145	585.992	(149)	0.952	0.968	0.040	(0.035, 0.044)
Self Liberation	1145	400.721	(149)	0.988	1.000	0.000	-
Stimulus Control	1145	574.927	(149)	0.944	0.963	0.041	(0.036, 0.045)

- Lower confidence limit negative, interval not calculated

Table 1.4. Unstandardized (with standard errors) and standardized longitudinal regression paths describing the mediation pathway; Processes of Change at baseline to mediator at 12 months (a_1) and mediator at 12 months to smoking outcome at 24 months (b_2)

Model	a_1	s.e.	Std. a_1	b_2	s.e.	Std. b_2
Mediator: Pros of Smoking						
Consciousness Raising	-0.378*	0.139	-0.256	-0.431*	0.108	-0.411
Dramatic Relief	-0.206*	0.102	-0.144	-0.454*	0.111	-0.418
Environmental Reevaluation	-0.136	0.077	-0.097	-0.479*	0.113	-0.437
Self-Reevaluation	-0.258*	0.096	-0.177	-0.495*	0.117	-0.460
Social Liberation	-0.368*	0.133	-0.243	-0.453*	0.108	-0.445
Counter Conditioning	0.177	0.223	0.123	-0.550*	0.130	-0.487
Helping Relationships	-0.069	0.076	-0.049	-0.518*	0.116	-0.462
Reinforcement Management	-0.075	0.076	-0.053	-0.495*	0.113	-0.449
Self Liberation	-0.072	0.083	-0.051	-0.501*	0.117	-0.451
Stimulus Control	-0.052	0.083	-0.037	-0.472*	0.115	-0.423
Mediator: Cons of Smoking						
Consciousness Raising	-0.510	0.300	-0.293	-0.103	0.076	-0.131
Dramatic Relief	-0.350*	0.164	-0.222	-0.145	0.072	-0.167
Environmental Reevaluation	-0.280*	0.109	-0.188	-0.217*	0.074	-0.237
Self-Reevaluation	-0.732*	0.283	-0.403	-0.169*	0.075	-0.222
Social Liberation	-0.803*	0.246	-0.477	-0.222*	0.068	-0.273
Counter Conditioning	-0.467	0.253	-0.328	-0.160	0.084	-0.158
Helping Relationships	-0.169*	0.082	-0.125	-0.274*	0.077	-0.269
Reinforcement Management	-0.176	0.095	-0.125	-0.240*	0.077	-0.249
Self Liberation	-0.309*	0.113	-0.213	-0.176*	0.071	-0.190
Stimulus Control	-0.171	0.109	-0.118	-0.204*	0.075	-0.219
Mediator: Situational Temptations						
Consciousness Raising	-0.375*	0.125	-0.275	-0.455*	0.124	-0.317
Dramatic Relief	-0.148*	0.071	-0.111	-0.457*	0.124	-0.305
Environmental Reevaluation	-0.132*	0.063	-0.100	-0.491*	0.126	-0.334
Self-Reevaluation	-0.090	0.077	-0.067	-0.491*	0.129	-0.339
Social Liberation	-0.154	0.105	-0.113	-0.509*	0.124	-0.361
Counter Conditioning	0.184	0.161	0.127	-0.457*	0.166	-0.332
Helping Relationships	-0.077	0.065	-0.057	-0.520*	0.125	-0.360
Reinforcement Management	-0.022	0.061	-0.016	-0.527*	0.129	-0.356
Self Liberation	-0.019	0.070	-0.014	-0.513*	0.124	-0.357
Stimulus Control	0.039	0.069	0.029	-0.490*	0.125	-0.332

** $p < 0.05$*

Table 1.5. Products, standard errors, 95% asymmetric confidence limits, and products of standardized coefficients for the Processes of Change that demonstrated statistical significance for both a_1 and b_1 paths

Model	Product of a_1 and b_1	s.e.	(95% Product)	Product of Std. a_1 and b_1
Mediator: Pros of Smoking				
Consciousness Raising	0.163	0.074	(0.038, 0.326)	0.105
Dramatic Relief	0.094	0.053	(0.003, 0.209)	0.060
Self-Reevaluation	0.128	0.057	(0.030, 0.254)	0.081
Social Liberation	0.167	0.074	(0.042, 0.328)	0.108
Mediator: Cons of Smoking				
Dramatic Relief	0.051	0.037	(-0.003, 0.136)	0.037
Environmental Reevaluation	0.061	0.032	(0.009, 0.134)	0.045
Self-Reevaluation	0.124	0.076	(0.006, 0.298)	0.089
Social Liberation	0.178	0.079	(0.048, 0.355)	0.130
Helping Relationships	0.046	0.027	(0.002, 0.106)	0.034
Self Liberation	0.054	0.031	(0.006, 0.124)	0.040
Mediator: Situational Temptations				
Consciousness Raising	0.171	0.075	(0.046, 0.337)	0.087
Dramatic Relief	0.068	0.038	(0.003, 0.153)	0.034
Environmental Reevaluation	0.065	0.036	(0.004, 0.144)	0.033

Figure 1.1. Autoregressive mediation model II template, with Processes of Change (P) as independent variables, mediating variables (M) as mediators, and smoking outcome (Smoking) as dependent variables; at the baseline, 12-month, and 24-month time points

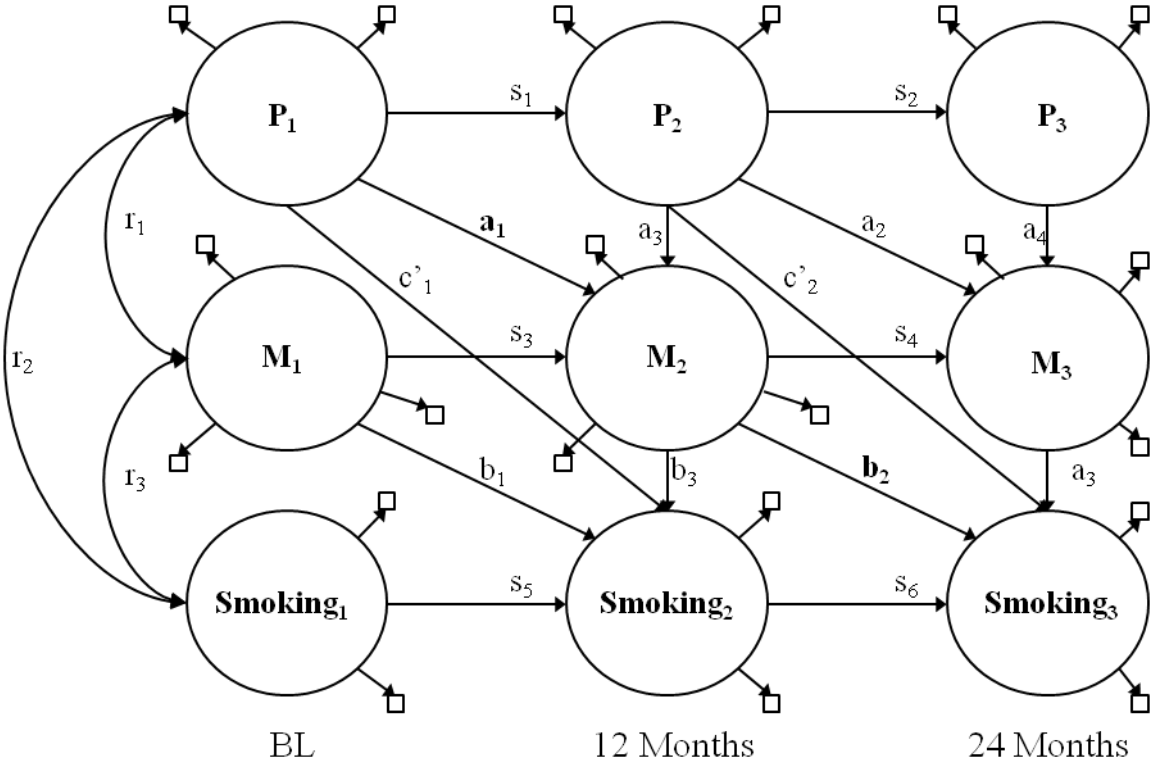
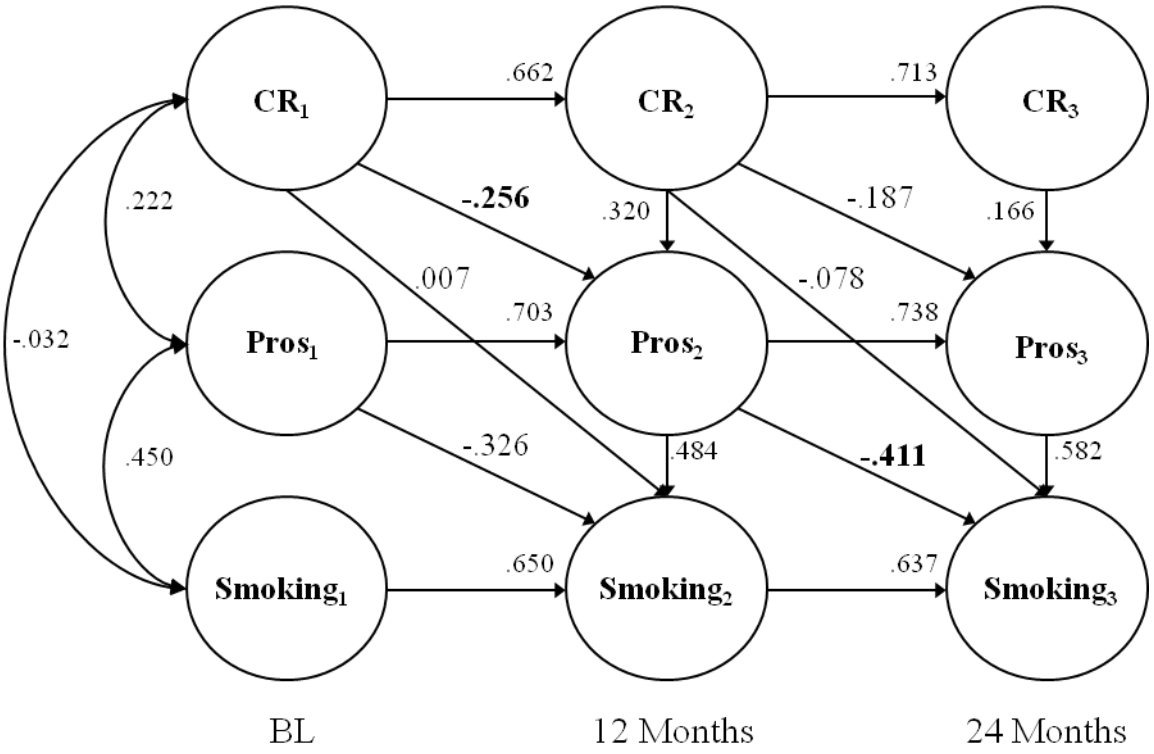
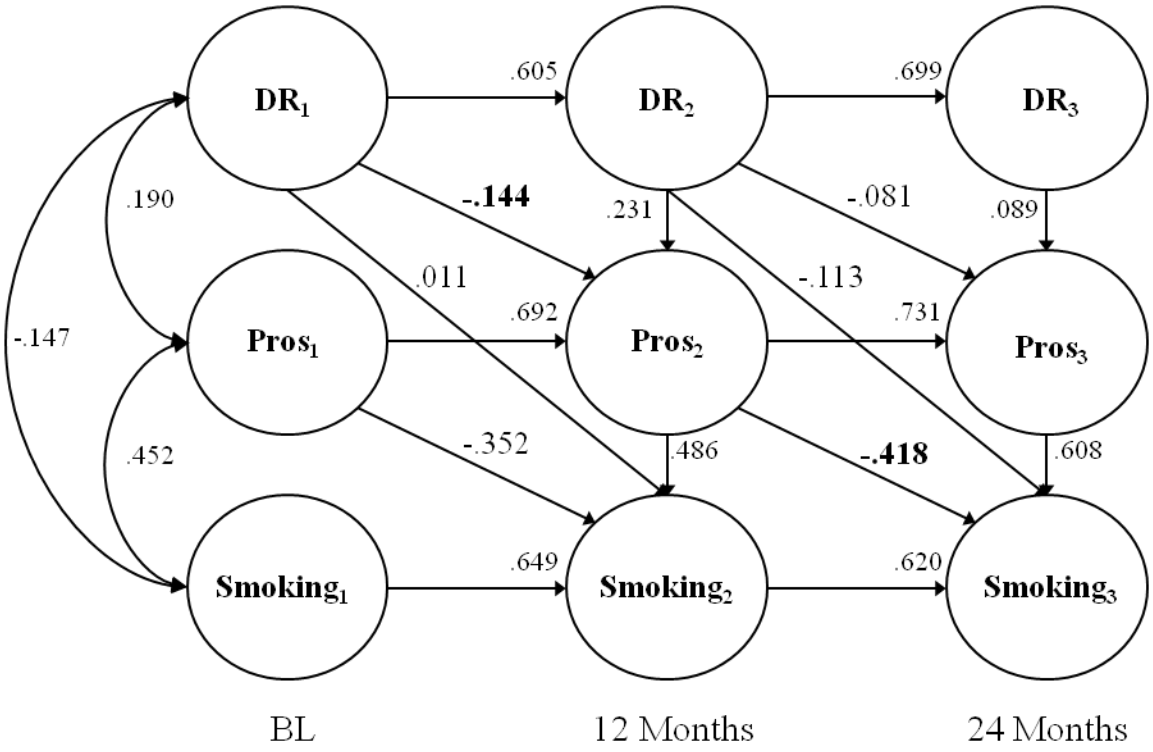


Figure 1.2. Single mediator model at PC; with Consciousness Raising (CR) as independent variables, Pros of Smoking (Pros) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



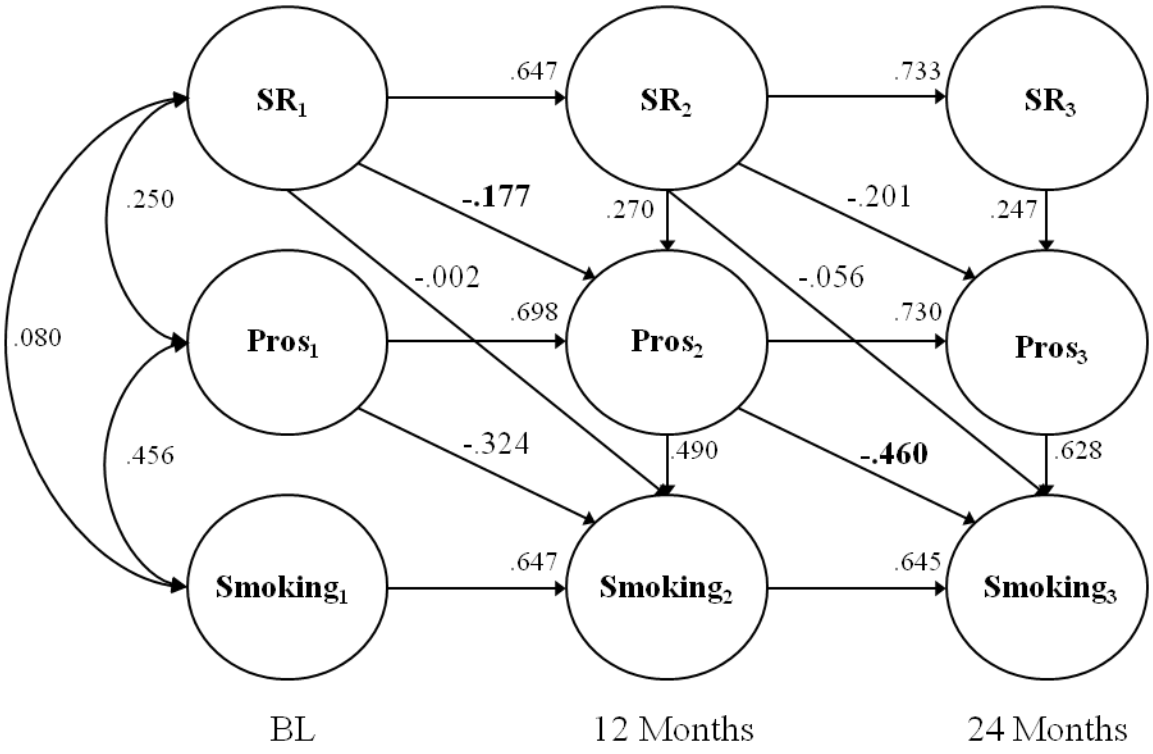
Product of standardized a_1 and b_2 paths = .105

Figure 1.3. Single mediator model at PC; with Dramatic Relief (DR) as independent variables, Pros of Smoking (Pros) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



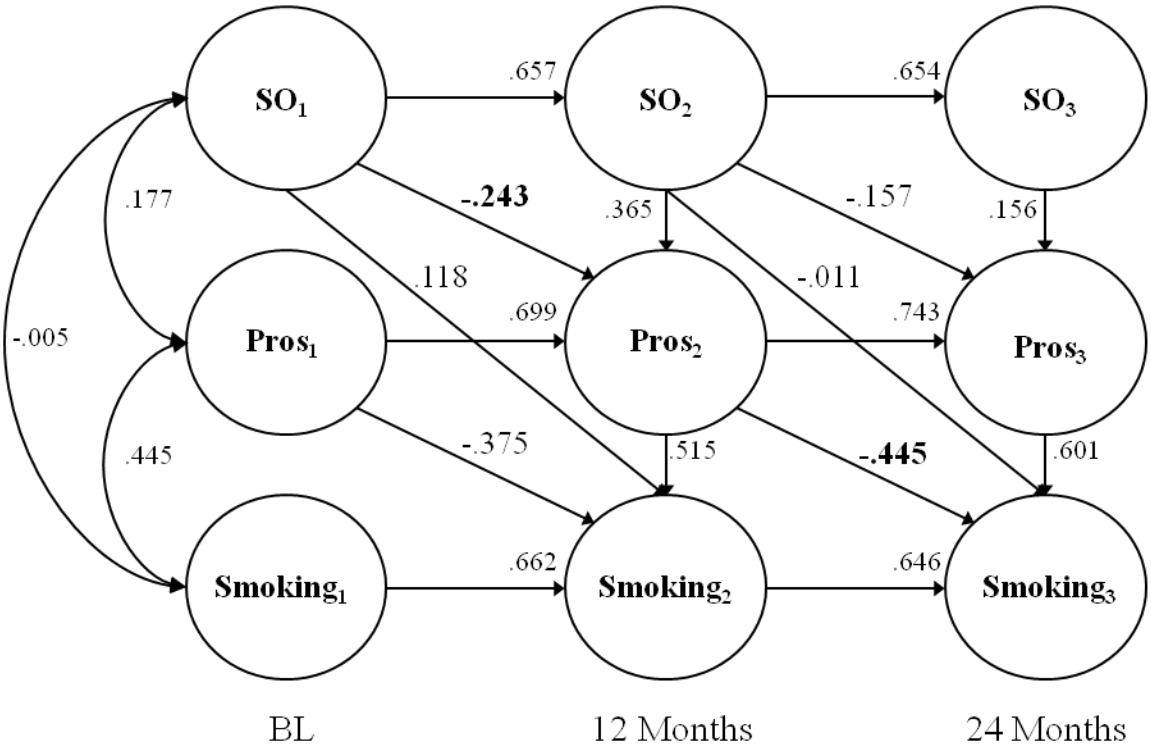
Product of standardized a_1 and b_2 paths = .060

Figure 1.4. Single mediator model at PC; with Self-Reevaluation (SR) as independent variables, Pros of Smoking (Pros) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



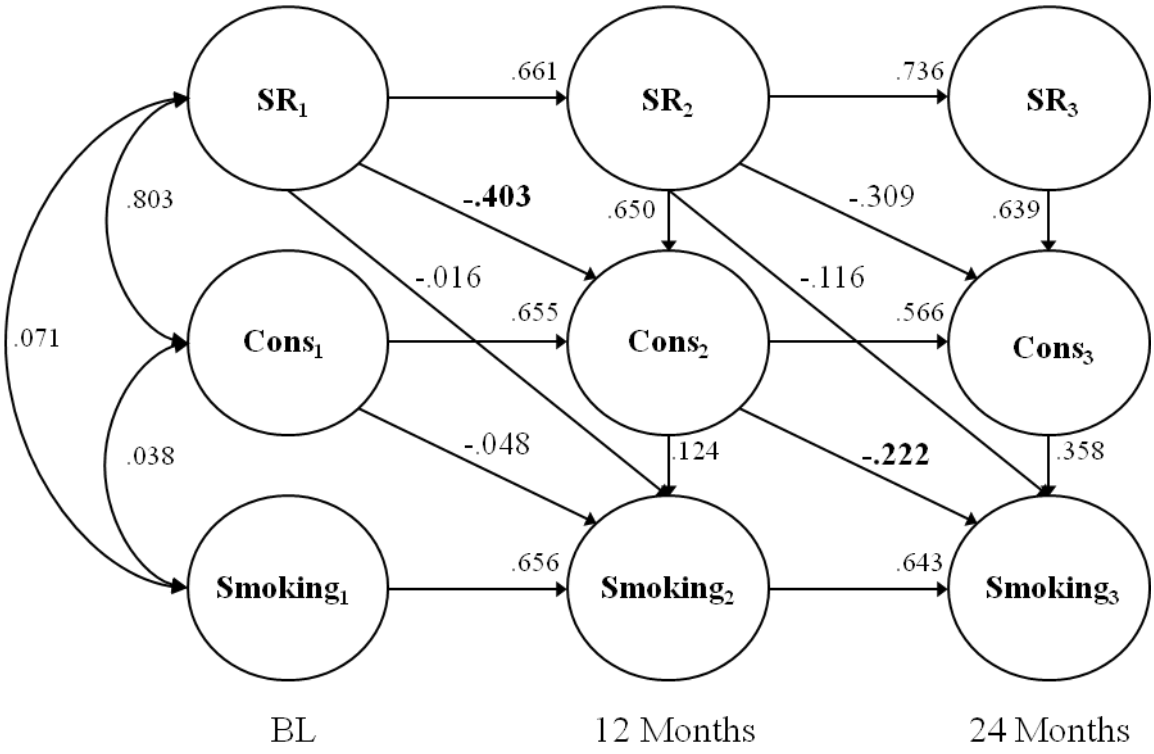
Product of standardized a_1 and b_2 paths = .081

Figure 1.5. Single mediator model at PC; with Social Liberation (SO) as independent variables, Pros of Smoking (Pros) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



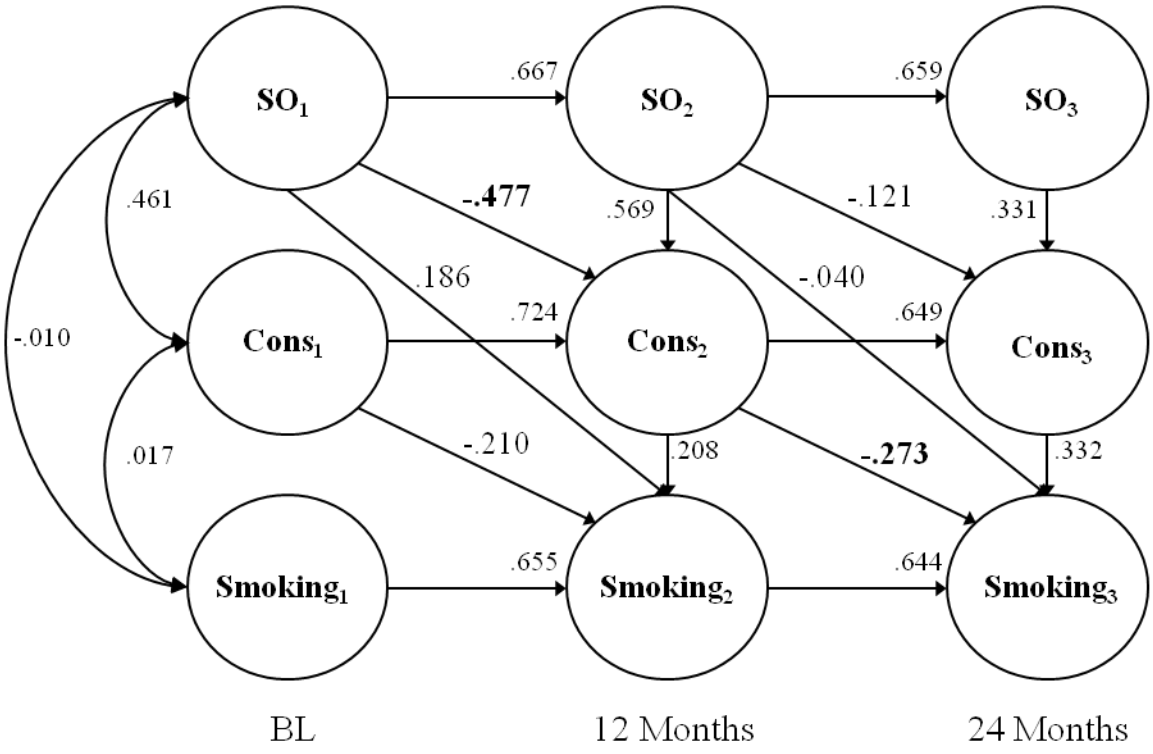
Product of standardized a_1 and b_2 paths = .108

Figure 1.6. Single mediator model at PC; with Self-Reevaluation (SR) as independent variables, Cons of Smoking (Cons) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



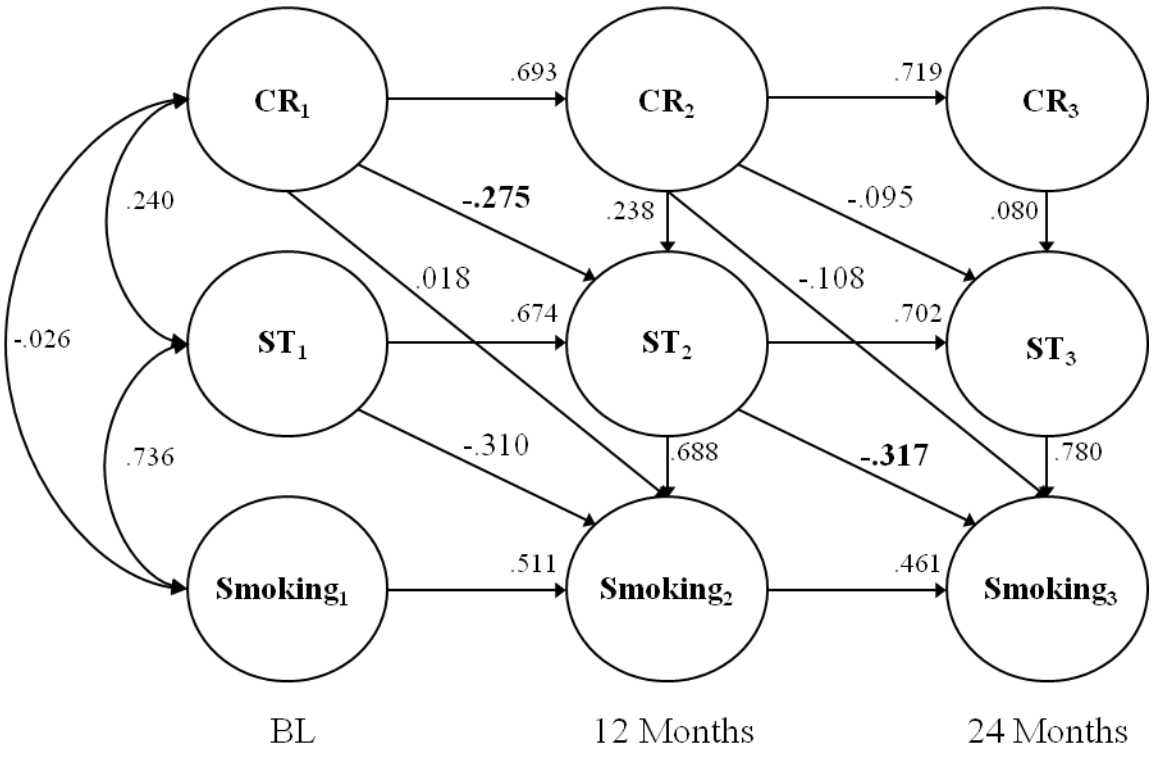
Product of standardized a_1 and b_2 paths = .089

Figure 1.7. Single mediator model at PC; with Social Liberation (SO) as independent variables, Cons of Smoking (Cons) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



Product of standardized a_1 and b_2 paths = .130

Figure 1.8. Single mediator model at PC; with Consciousness Raising (CR) as independent variables, Situational Temptations (ST) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



Product of standardized a_1 and b_2 paths = .087

MANUSCRIPT 2

Investigating the Mechanisms of Smoking Behavior Change: Single Mediator Models for Smokers in the Contemplation Stage

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Abstract

Investigating and quantifying the mechanisms that underlie behavior change is essential to understanding what drives effective interventions. While many population-based smoking interventions have a theoretical framework, the mechanisms that impact behavior change during the intervention are rarely explored empirically. Better understanding variables that explain changes in smoking behavior can provide a basis for more direct and effective interventions. The present study combined data (N = 1243) from five randomized Transtheoretical Model (TTM)-tailored intervention studies. Statistical mediation analysis with autoregressive, three-wave models was utilized to investigate changes in behavioral variables across three time points (baseline, 12 months, and 24 months) for participants in the contemplation stage (C; smokers intending to quit in the next six months) at baseline. The ten Processes of Change for Smoking were used as independent variables, Pros of Smoking, Cons of Smoking, and Situational Temptations to Smoke were used as mediators, and a behavioral smoking outcome was used as the dependent variable for a total of 30 separate mediation models. Models were assessed with structural equation modeling, and all demonstrated very good fit (CFI > 0.95; RMSEA < 0.05). The Pros, Cons, and Situational Temptations all demonstrated evidence of statistical mediation with multiple Processes of Change. Some of the most important Processes of Change for participants in C at baseline were: Consciousness Raising, Dramatic Relief, Environmental Reevaluation, Self-Reevaluation, Social Liberation, and Counter Conditioning. Development and refinement of statistical mediation models to assess the mechanisms of behavior change are crucial to enhancing basic knowledge and informing intervention efforts.

Keywords: Statistical Mediation Analysis, Smoking Cessation, Transtheoretical Model, Contemplation Stage

Investigating the Mechanisms of Smoking Behavior Change:

Single Mediator Models for Smokers in the Contemplation Stage

Mechanisms of behavior change explain how and why behavior change occurs. Better understanding behavioral mechanisms necessitates better understanding variables that account for observed changes in behavior. Despite the importance of mechanisms of behavior change, knowledge about these mechanisms is presently very limited (NIH, 2009; 2012). Investigating and quantifying such mechanisms that underlie behavior change is essential to understanding what drives effective interventions. Many interventions follow a "black-box" approach, where the intervention components are related to the intervention outcomes, with no empirical investigation of what drives these outcomes. Many content areas would greatly benefit from a comprehensive investigation of the mechanisms that drive behavior change.

Due to its extreme consequences, cigarette smoking represents a key health behavior that needs to be better understood. Despite decades of prevention and intervention efforts, smoking remains a critical concern for public health in the United States. Approximately 19% of U.S. adults are smokers, and while smoking prevalence rates have decreased from approximately 42% in 1965, this decrease seems to be slowing (Centers for Disease Control [CDC], 2011a; 2011b; 2012). An estimated 443,000 adults die from smoking-related illnesses every year, and smoking is estimated to cost the United States $96 billion and $97 billion in direct medical expenses and lost productivity, respectively (CDC, 2008; 2012). An older estimate suggests that of all the people alive in the world today, 500,000,000 are expected to die from tobacco use (Peto & Lopez, 1990). Given the extreme health and economic costs of smoking, improving interventions to help smokers quit is of paramount importance. Over two-thirds of smokers report that they want to quit smoking (CDC, 2011c). Better understanding the behavioral mechanisms that help smokers change their behavior will emphasize behavioral strategies to aid quitting smoking and address a major health concern.

The present study combined data from multiple intervention studies that effectively reduced smoking and utilized statistical mediation analysis to examine the mechanisms of smoking behavior change. Statistical mediation analysis is an advanced methodology that is ideal for investigating and quantifying mechanisms of behavior change. These tailored intervention studies were based on a widely-studied model of behavior change, the Transtheoretical Model (TTM).

Statistical Mediation Analysis

In general, mediation models are utilized to investigate how and why two things are related. Intermediate variables that come between independent variables and dependent variables are known as mediating variables, or mediators. A mediator acts as a third variable and represents the mechanism through which an independent variable influences an outcome (Baron & Kenny, 1986). The most basic model (MacKinnon, 2008) involves three key variables: an independent variable, X, a mediating variable, M, and a dependent variable, Y. From this simple model, additional independent variables, mediating variables, time points, and other components can be added to develop increasingly complex mediation models. In the framework of an intervention designed to change behavior, mediators are the mechanisms of behavior change. Thus, statistical mediation analysis was utilized in the present study to develop empirical models to better understand behavior change mechanisms.

A critical feature of the present series of mediation analyses is that all mediation models were longitudinal. Mediation models are also referred to as causal models, as mediators are hypothesized to cause changes in the dependent variables (and not the other way around) (Baron & Kenny, 1986). Thus, developing mediation models that demonstrate change over time requires longitudinal data to study the temporal order of change, as behavior change cannot be assumed to occur instantly. While mediation analyses can be performed with cross sectional data, the conclusions that can be drawn from such analyses are very limited (Gallob & Reichardt, 1991). Cross-sectional mediation analyses should be considered both inadequate and inappropriate to

study mechanisms of behavior change (Kazdin & Nock, 2003). Longitudinal mediation models require fewer assumptions, provide more accurate descriptions of the temporal order of change, and offer a more comprehensive evaluation of the mechanisms of change (MacKinnon, 2008).

The Transtheoretical Model of Behavior Change

The Transtheoretical Model is an integrative framework that consists of multiple dimensions that assess different components of behavior change (Prochaska & Velicer, 1997; Velicer, Prochaska, Fava, Rossi, Redding, Laforge, & Robbins, 2000). Essentially, the TTM represents a model of how individuals adopt healthy behaviors and discontinue unhealthy ones (Brewer & Rimer, 2008). The core constructs of the TTM include stages of change, processes of change, decisional balance, and self-efficacy. Tailored interventions based on the TTM have been empirically validated and have demonstrated effectiveness for a wide variety of behaviors, including smoking (Krebs, Prochaska, & Rossi, 2010; Noar, Benac, & Harris, 2007; Velicer, Prochaska, & Redding, 2006b; Velicer, Redding, Sun, & Prochaska, 2007b). The overall framework of the TTM is ideal for the development of mediation models because it can be conceptually summarized with three dimensions (Velicer et al., 2000): the temporal dimension (stages of change), the independent variable dimension (processes), and the intermediate variable dimension (decisional balance and self-efficacy).

Smoking research and the TTM have a very extensive history. Multiple components of the TTM were empirically refined with smoking as the content area, including stage of change (DiClemente et al., 1991), processes of change (Prochaska & DiClemente, 1983; Prochaska, Velicer, DiClemente, & Fava, 1988), decisional balance (Velicer, DiClemente, Prochaska & Brandenberg, 1985), and self-efficacy (Velicer, DiClemente, Rossi, & Prochaska, 1990), with longitudinal studies supporting predictive validity in some randomized and some nonrandomized studies (DiClemente et al., 1991; Prochaska, Velicer, Fava, Rossi, & Tsoh, 2001; Prochaska et al., 2004, 2005; Redding et al., 2011; Sun, Prochaska, Velicer, & LaForge, 2007; Velicer et al., 2006b, 2007b). The TTM has been applied to a wide variety of behaviors (e.g., alcohol use,

exercise, diet, UV protection, mammography screening), but it has been most widely applied to smoking (Krebs et al., 2010; Noar et al., 2007).

Mechanisms of Behavior Change and Interventions

Data from five TTM- tailored smoking interventions were utilized in the present study, and statistical mediation analysis was used to quantitatively deconstruct these intervention studies and determine which components, and which combinations of components, produced the treatment outcomes. Previous studies have explored potential mediators of smoking interventions with different statistical methods. Of particular relevance to the present study, some past research has investigated self-efficacy as a potential mediator of smoking cessation. Some studies have suggested that self-efficacy may function as a mediator of smoking cessation (Cinciripini et al., 2003; Vidrine, Arduino, & Gritz, 2006), while others have found mixed results (Gwaltney, Shiffman, Balabanis, & Paty, 2005; Unger et al., 2000). The present study investigated self-efficacy, as well as pros and cons, as mediators.

Overview of Current Study

Smokers that were identified as being in the contemplation (C) stage at the start of intervention were the focus of the present study. This is the second of a series of six studies that utilized statistical mediation analysis to better understand mechanisms of smoking behavior change in TTM-based studies. The first study focused on smokers in the precontemplation (PC) stage, and the third study focused on smokers in the preparation (PR) stage. Statistical mediation models were developed within separate stages, as opposed to combining individuals across stages, because differences in stage have consistently demonstrated nonlinear relations with the other TTM variables (Velicer, Prochaska, Rossi, DiClemente, 1996). The C stage for smoking cessation includes smokers that are intending to quit in the next six months. Individuals in this stage are interested in quitting, and are utilizing strategies to change, including the Processes of Change for Smoking, more than individuals in the PC stage (DiClemente et al., 1991; Fava et al., 1995). Compared to the other stages, contemplators typically report the highest cons of smoking

(Hall & Rossi, 2008; Velicer et al., 1985). In PC, the pros of smoking outweigh the cons; this balance shifts in the C stage, with the cons now outweighing the pros. Situational Temptations to smoke remain comparatively high for contemplators but will decrease as these individuals progress towards nonsmoking.

The goal of the present study was to conduct a comprehensive series of statistical mediation analyses with data from TTM-based intervention studies to identify, for participants that were in the C stage at baseline, which combinations of intervention components demonstrated empirical evidence of mediation. The analytical framework was guided by the TTM, with the ten processes of change acting as independent variables, pros, cons, and self-efficacy acting as mediators, and a smoking behavior outcome acting as the dependent variable. Each of the models only included one mediator, in order to isolate separate intervention components. All models were longitudinal, with data from assessments at three time points (baseline, 12 months, and 24 months). These variables produced a series of 30 single mediator models (10 processes * 3 mediators * 1 outcome) that were analyzed.

Method

Participants

Data from five different smoking intervention studies were combined in the present study. Combining data from multiple large studies was a necessary step to create a sample size large enough to analyze the complex statistical mediation models. These studies could be combined because of a number of crucial similarities. All five studies were large, randomized, clinical trials that were successful in decreasing smoking rates. Each study collected longitudinal data, used representative, population-based sampling, and assessed all key TTM constructs (with the same items) necessary to run the mediation analyses. Only participants that received the same TTM-based smoking intervention were included in the combined sample; participants in control conditions or in other treatment groups were not included. Checking the validity of combining these studies by comparing within-study mediation models was included in a separate study

(manuscript 6 in the present series of studies). The five separate studies that make up the combined sample were labeled Parent, Patient, Worksite, RDD, and Health. Sample sizes included below represent participants in C at baseline.

Original Studies. The Parent study (Prochaska et al., 2004) involved parents of students recruited for a school-based study (N=145). In addition to a smoking intervention, participants in this study who were at risk also received interventions on diet and sun exposure. The Patient study (Prochaska et al., 2005) involved patients from an insurance provider list (N=287). In addition to a smoking intervention, participants in this study who were at risk also received interventions on diet, sun exposure, and mammography. The Worksite study (Velicer et al., 2004) involved employees from a sample of worksites (N=80). In addition to a smoking intervention, participants in this study who were at risk also received interventions on diet, sun exposure, and exercise. The RDD study (Prochaska et al., 2001) involved participants from a random digit dial (RDD) sample (N=565). This study intervened only on smoking. The Health study (Velicer, Friedman, Redding, Migneault, & Hoeppner, 2006a; Velicer, Friedman, Redding, Migneault, Hoeppner, & Prochaska, 2007a) involved participants who were smokers and who were at risk for diet and exercise in a multiple risk behavior study (N=166). In addition to a smoking intervention, participants in this study also received interventions on diet and exercise.

Total Combined Sample. The total combined sample for participants in C at baseline was N = 1243. Participants were 61.9% female and 92.1% white.

Intervention

All participants received a TTM-tailored smoking intervention that assessed key variables at baseline, 12 months, and 24 months. The smoking intervention was a tailored, expert system intervention, where participants received feedback matched to how they responded to TTM constructs. All interventions began with an assessment of basic demographic variables, smoking variables, and the core measures from the TTM. Interventions provided stage-matched and tailored feedback in a series of three reports at baseline, 3 months, and 6 months (RDD) or at

baseline, 6 months, and 12 months (Parent, Patient, Worksite, and Health). Tailoring in these feedback reports involved both highlighting certain strategies to change (processes of change) as well as normative and ipsative comparisons. Data from studies with different intervention schedules were combined because these two different schedules did not produce different results (Velicer et al., 2007b). Participants in all interventions also received multiple follow-up assessments. Additional details involving the expert system intervention are available elsewhere (Velicer & Prochaska, 1999; Velicer et al., 1993).

Measures

Analyses performed in the present study involved all core TTM constructs, including stage of change, processes of change, decisional balance, and self-efficacy. Additional variables, related to smoking behavior, were also used to measure a latent variable for smoking outcome.

Stage of Change. The stages of change represent the temporal dimension of TTM and act as the central organizing framework of the model. Varying levels of readiness to change are represented by five stages: Precontemplation (PC), Contemplation (C), Preparation (PR), Action (A), and Maintenance (M) (DiClemente et al., 1991; Prochaska & DiClemente, 1983). Stages of change for smoking were assessed with algorithms developed to assess intentions to quit smoking (Prochaska & DiClemente, 1983). The C stage includes participants that report being smokers and report intending to quit in the next six months. The C stage also includes participants that reported intending to quit in the next month but did not have a successful 24-hour quit attempt in the past year.

Processes of Change. The processes of change represent the independent variable dimension of the TTM. The processes involve strategies for changing one's behavior; in TTM-based interventions, the processes play a critical role in tailoring the intervention to the individual. There are ten Processes of Change for Smoking (Prochaska et al., 1988). The ten processes include experiential processes, which are cognitive and emotional strategies to change behavior, and behavioral processes, which represent more overt changes in behavior. The

experiential processes include Consciousness Raising, Dramatic Relief, Environmental Reevaluation, Self-Reevaluation, and Social Liberation. The behavioral processes include Counter Conditioning, Helping relationships, Reinforcement Management, Self Liberation, and Stimulus Control. Detailed descriptions of the Processes of Change for Smoking are available elsewhere (Prochaska et al., 1988). Participants were asked to rate how often they used each process in the last month on a 5-point Likert scale ranging from 1 (Never) to 5 (Repeatedly). Each of the processes was a latent variable measured by two items; details for the items are included in Appendix A. In the total sample, coefficient alphas for the Processes of Change for Smoking scales ranged from 0.60 to 0.84.

Decisional Balance. The decisional balance construct represents part of the intermediate variable dimension of the TTM. Decisional balance, originally adapted from Janis and Mann (1977), assess an individual's weighing of the pros and cons of engaging in a behavior. The relationship between decisional balance and the stages of change has been replicated across more than 48 different health behaviors (Hall & Rossi, 2008). The Decisional Balance Scale for Smoking is a six-item scale with three items for the Pros of Smoking and three items for the Cons of Smoking (Velicer et al., 1985). These items assess the relative importance of the pros and cons of smoking. Participants were asked to rate the importance of each item on a 5-point Likert scale ranging from 1 (Not important) to 5 (Extremely important). The Pros of Smoking and the Cons of Smoking were represented by latent variables, each measured by three items; details for the items are included in Appendix A. In the total sample, coefficient alpha was 0.70 for the Pros of Smoking and 0.66 for the Cons of Smoking.

Self-Efficacy. The self-efficacy construct represents the other part of the intermediate variable dimension of the TTM. Originally adapted from Bandura (1977), the self-efficacy construct assesses an individual's perceived ability to perform behaviors in difficult situations. Self-efficacy increases as one transitions TTM stages (Velicer et al., 1990). Improved self-efficacy predicts improved outcomes; this relationship has been repeatedly demonstrated for

smoking (Blissmer et al., 2010; Prochaska, DiClemente, Velicer, Ginpil, & Norcross, 1985; Prochaska, Velicer, DiClemente, Guadagnoli, & Rossi, 1991). In the framework of the TTM, self-efficacy either describes the confidence to engage in a healthy behavior or describes temptations to engage in an unhealthy behavior. For smoking, self-efficacy is measured by the Situational Temptations to Smoke scale (Velicer et al., 1990). The Situational Temptations describe situations that may lead some people to smoke. The instrument is a nine-item scale with three items for positive affect / social situations, three items for negative affect situations, and three items for habitual / craving situations. Participants were asked to rate how tempted to smoke they felt on a 5-point Likert scale ranging from 1 (Not at all tempted) to 5 (Extremely tempted). Details for the items are included in Appendix A. In the present study, averages of these three item content areas (e.g., positive affect / social situations) were calculated to represent Situational Temptations for Smoking with three items; a latent variable for Situational Temptations was measured by these three items. Coefficient alpha for this three-item scale was 0.78 in the total sample.

Smoking Outcome. The smoking behavioral outcome was a latent variable measured by two key items from the widely-used Fagerstrom Test for Nicotine Dependence (FTND; Fagerstrom, 1978), time to first cigarette and number of cigarettes smoked per day. These two continuous variables were converted to 5-point scales, with higher values indicating more smoking. Details for the items are included in Appendix A. Coefficient alpha for this measure was 0.75 in the total sample.

Statistical Analysis

Development of the series of 30 single mediator models can be summarized by two phases of analysis. The first phase involved the creation of models that best fit the data. The second phase involved the assessment of paths within the models to search for evidence of statistical mediation.

Creation and Fit Assessment of Mediation Models. Developing models that fit the data is essential to establishing a framework for statistical mediation. Creation of the single-mediator models was guided by the hypothesized TTM framework, where processes are the independent variables (X), decisional balance (pros, cons) and self-efficacy are mediators (M), and the smoking outcome is the dependent variable (Y). In the present study, only participants that were C at baseline were included. This set of variables (10 processes * 3 mediators * 1 outcome) produced a total of 30 single-mediator models.

All of the mediation models in the present study were latent variable models. The use of latent variables improves the reliability of the measures (MacKinnon, 2008). Data were available at baseline, 12 months, and 24 months, and therefore all mediation models were longitudinal, three-wave models. These models represent autoregressive mediation models (Cole & Maxwell, 2003; Gallob & Reichardt, 1991, MacKinnon, 2008). In longitudinal, autoregressive, three-wave mediation models, each variable is predicted by the same variable at an earlier wave. Due to the number of parameters being estimated in each model, and the use of latent variables, structural equation modeling (SEM) was an ideal analytic tool to assess these mediation models (Iacobucci, Saldanha, & Deng, 2007; MacKinnon, 2008).

SEM was utilized to analyze the covariance structure, estimate regression paths, estimate error terms, and assess model fit. Missing data, which are extremely common in longitudinal studies, were estimated with maximum likelihood (ML) procedures. Using ML methods in SEM has been demonstrated to be accurate and less biased than conventional methods such as listwise or pairwise deletion (Allison, 2003; Enders & Bandalos, 2001). The following commonly-used indices were used as benchmarks to assess the model fit: likelihood ratio chi-square ($\chi 2$), Normed Fit Index (NFI), Comparative Fit Index (CFI), and Root Mean Squared Error of Approximation (RMSEA). Likelihood ratio chi-square provides a test for fit of the model based on the chi-squared distribution. The chi-square test is extremely sensitive to large sample sizes (Kline, 2005) and will always reject models with large sample sizes. Due to this issue, and the large sample

sizes in the present study, chi-square values are reported but results for its associated significance test are not. For NFI and CFI, values greater than 0.90 indicate good fit and values greater than 0.95 indicate very good fit (Bentler & Bonnet, 1980; Kline, 2005). For RMSEA, values less than 0.10 indicate good fit and values less than 0.05 indicate very good fit (Browne & Cudeck, 1993). An important goal of creating longitudinal mediation models in SEM was to find a model that fit well across all 30 single mediator combinations. A common underlying model created the opportunity to compare results across the 30 single mediator models.

Assessing Statistical Mediation. Evaluating the regression paths was necessary to determining which combinations of variables actually demonstrated empirical evidence of statistical mediation. Analysis with SEM includes the estimation of regression paths among the variables. In three-wave autoregressive mediation models, two paths are particularly important to mediation: X at time 1 to M at time 2 (path a_1) and M at time 2 to Y at time 3 (path b_2). Together, these two paths represent the mediation pathway, which is also known as the indirect effect or the intervening effect (MacKinnon, Lockwood, & Williams, 2004; Preacher & Hayes, 2008; Sobel, 1982). Statistical significance of each of these paths was assessed separately in SEM; if each path demonstrated statistical significance, this finding suggests that the mediation pathway may be significant. To further assess for evidence of mediation, asymmetric confidence intervals for the product of these paths were calculated (MacKinnon, 2008; Tofighi & MacKinnon, 2011). If the confidence interval did not include zero, there was evidence of statistical mediation.

There is no consensus on what estimates best represent effect sizes for statistical mediation analysis, and this topic represents an area that is currently under refinement (Fairchild, MacKinnon, Taborga, & Taylor, 2009; Preacher & Kelly, 2011; MacKinnon, 2008). In the present study, standardized coefficients for a_1 and b_1 were reported, as well as the product of the standardized coefficients (MacKinnon, 2008). These estimates help describe the magnitude of the mediated effect and will be interpreted similarly to R^2, where product absolute values of 0.01, 0.06, and 0.13 correspond to small, medium, and large effect sizes (Cohen, 1992).

Results

Creation and Fit Assessment of Mediation Models

As a first step, descriptive analyses were performed on the combined dataset (N = 1243) to check for extreme skewness and kurtosis values for the study variables (West, Finch, & Curran, 1995). All skewness variables and kurtosis values were between -2 and 2. Basic descriptive statistics for the averages of study variables (means and standard deviations) are included in Table 2.1.

SEM was employed with EQS 6.1 software (Bentler, 2007) to develop the single mediator models. Suggestions from Cole and Maxwell (2003) and MacKinnon (2008) were utilized to create a variety of autoregressive mediation models, including a basic autoregressive mediation model (autoregressive mediation model I), a more advanced model (autoregressive mediation model II), and a fully cross-lagged model. Fit statistics across these sample models consistently suggested that an autoregressive model II best fit the data. The template for the autoregressive mediation model II is included in Figure 2.1. There are six key characteristics to the autoregressive mediation model II (MacKinnon, 2008). First, relations are modeled one lag apart (e.g., 12 months to 24 months). Second, relations between the same variables over time are modeled to assess stability (the *s* coefficients). Third, the model includes regression paths that describe longitudinal mediation (e.g., independent variable at time 1 to mediator at time 2, independent variable at time 1 to dependent variable at time 2). Fourth, covariances among the variables at the first wave are estimated. Fifth, covariances among error terms are estimated at each wave. Sixth, relations between the independent variable and mediator, as well as mediator and dependent variable, are modeled. This is called contemporaneous mediation; the purpose of these paths is to help account for change that occurs between the time points. With the autoregressive model II framework selected, all 30 single mediator models were created.

Model Fit Statistics. The series of 30 mediation models (10 processes * 3 mediators * 1 outcome) were successfully created. First, the models were conducted using complete cases only.

Fit statistics from the complete case analysis are included in Table 2.2. With the Pros of Smoking as mediators, all models demonstrated a very good fit, with CFI values consistently above 0.95 and RMSEA values consistently below 0.05. With the Cons of Smoking as mediators, nearly all models demonstrated a very good fit (CFI > 0.95, RMSEA < 0.05). The model with Counter Conditioning demonstrated a good fit (close to very good; CFI = 0.948, RMSEA = .052). With Situational Temptations as mediators, nearly all models demonstrated a very good fit (CFI > 0.95, RMSEA < 0.05). The models with Counter Conditioning (CFI = 0.967, RMSEA = 0.050) and Helping Relationships (CFI = 0.944, RMSEA = 0.071) both demonstrated good fits.

Second, due to the large number of participants that had missing data on one or more of the variables (over 50% of the sample), the models were conducted using ML to estimate missing data. Fit statistics from the ML models are included in Table 2.3. The conclusions from these fit statistics matched the complete case analysis, with all models demonstrating exceptional fit.

Assessing Statistical Mediation

To assess the models for evidence of statistical mediation, the longitudinal regression paths estimated in SEM were evaluated. The mediation pathway (process at baseline to mediator at 12-months, a_1, and mediator at 12-months to outcome at 24-months, b_2) within each model was assessed in two steps. First, the statistical significance of each path (a_1 and b_2 in Figure 2.1) was assessed. Second, the RMediation (Tofighi & MacKinnon, 2011) application was employed to estimate asymmetric confidence intervals for the product of these paths. Models estimated with complete case analysis and models estimated with ML for missing data were assessed for evidence of statistical mediation. In all cases, the conclusions from both sets of models were equivalent. Results from models that included missing data estimation with ML are reported, as these estimates are less biased (Allison, 2003; Enders & Bandalos, 2001). Diagrams are included for models where the mediation pathway demonstrated a medium or greater effect size.

Statistical Mediation with Pros of Smoking as Mediator. Unstandardized and standardized longitudinal regression paths describing the mediation pathway through the Pros of

Smoking are included in Table 2.4. Six processes demonstrated statistical significance for both components of the mediation pathway. These processes, with standardized regression paths, were: Consciousness Raising (std. a_1 = -0.251, std. b_2 = -0.360); Dramatic Relief (std. a_1 = -0.212, std. b_2 = -0.348); Environmental Reevaluation (std. a_1 = -0.110, std. b_2 = -0.362); Self-Reevaluation (std. a_1 = -0.217, std. b_2 = -0.361); Social Liberation (std. a_1 = -0.173, std. b_2 = -0.356); and Counter Conditioning (std. a_1 = 0.226, std. b_2 = -0.490).

Products, confidence intervals, and products of standardized coefficients are included in Table 2.5. All six of the previously identified processes had confidence intervals that did not include zero: Consciousness Raising (0.039, 0.299; std. product = 0.090, medium effect; Figure 2.2); Dramatic Relief (0.024, 0.255; std. product = 0.074, medium effect; Figure 2.3); Environmental Reevaluation (0.007, 0.142; std. product = 0.040, small-medium effect); Self-Reevaluation (0.040, 0.251; std. product = 0.078, medium effect; Figure 2.4); Social Liberation (0.025, 0.203; std. product = 0.062, medium effect; Figure 2.5); and Counter Conditioning (-0.338, -0.060; std. product = -0.111, medium-large effect; Figure 2.6). These six Processes of Change for Smoking demonstrated evidence of statistical mediation with the Pros of Smoking as a mediator.

Statistical Mediation with Cons of Smoking as Mediator. Unstandardized and standardized longitudinal regression paths describing the mediation pathway through the Cons of Smoking are included in Table 2.4. Five processes demonstrated statistical significance for both components of the mediation pathway. These processes, with standardized regression paths, were: Environmental Reevaluation (std. a_1 = -0.181, std. b_2 = -0.137); Self-Reevaluation (std. a_1 = -0.331, std. b_2 = -0.165); Social Liberation (std. a_1 = -0.294, std. b_2 = -0.214); Self Liberation (std. a_1 = -0.130, std. b_2 = -0.141); and Stimulus Control (std. a_1 = -0.175, std. b_2 = -0.117).

Products, asymmetric confidence intervals, and products of standardized coefficients are included in Table 2.5. Three out of the five previously identified processes had confidence intervals that did not include zero: Environmental Reevaluation (0.004, 0.085; std. product =

0.025, small effect); Self-Reevaluation (0.009, 0.191; std. product = 0.055, small-medium effect); and Social Liberation (0.016, 0.239; std. product = 0.063, medium effect; Figure 2.7). These three Processes of Change for Smoking demonstrated evidence of statistical mediation with the Cons of Smoking as a mediator. Self Liberation (0.000, 0.070; std. product = 0.018) and Stimulus Control (0.000, 0.079; std. product = 0.020) had a confidence intervals that included zero, which suggests that these processes did not demonstrate meaningful evidence of statistical mediation through the Cons of Smoking.

Statistical Mediation with Situational Temptations as Mediator. Unstandardized and standardized longitudinal regression paths describing the mediation pathway through the Situational Temptations to Smoke are included in Table 2.4. Three processes demonstrated statistical significance for both components of the mediation pathway. These processes, with standardized regression paths, were: Self-Reevaluation (std. a_1 = -0.255, std. b_2 = -0.331); Counter Conditioning (std. a_1 = 0.131, std. b_2 = -0.403); and Stimulus Control (std. a_1 = 0.162, std. b_2 = -0.318).

Products, asymmetric confidence intervals, and products of standardized coefficients are included in Table 2.5. All three of the previously identified processes had confidence intervals that did not include zero: Self-Reevaluation (0.062, 0.312; std. product = 0.084, medium effect; Figure 2.8); Counter Conditioning (-0.240, -0.006; std. product = -0.053, small-medium effect); and Stimulus Control (-0.208, -0.031; std. product = -0.052, small-medium effect). These three Processes of Change for Smoking demonstrated evidence of statistical mediation with Situational Temptations as a mediator.

Discussion

Advanced statistical mediation analysis techniques were utilized to investigate variables hypothesized to underlie changes in smoking behavior. A series of 30 single mediator models for participants in the C stage for smoking at baseline was successfully conducted. Smokers in the C stage reported intentions to quit smoking in the next six months. All models utilized the

framework of an autoregressive mediation model II (MacKinnon, 2008), had three time points (baseline, 12 months, and 24 months), and employed SEM to estimate covariance structure, regression paths, error terms, missing data with ML, and assess model fit. All models demonstrated a great fit, and a total of 12 combinations of processes and mediators demonstrated evidence of statistical mediation.

Models with the Pros of Smoking as Mediator

The Pros of Smoking represent positive or appealing aspects of cigarette smoking and their importance to the smoker (Velicer et al., 1985). The Pros were hypothesized as a potential mediator because of empirical evidence that the Pros of Smoking typically decrease as a smoker makes progress to quitting smoking (Hall & Rossi, 2008). For participants starting intervention in the C stage, six Processes of Change for Smoking were found to demonstrate evidence of statistical mediation through the Pros of Smoking. They were Consciousness Raising, Dramatic Relief, Environmental Reevaluation, Self-Reevaluation, Social Liberation, and Counter Conditioning. Evidence from significance tests of regression paths and asymmetric confidence intervals suggest that each of these processes influenced the Pros, which in turn influenced the smoking outcome.

The Processes of Change for Smoking have a correlated higher-order factor structure with two dimensions: experiential processes and behavioral processes (Prochaska et al., 1988). The experiential processes involve cognitive and emotional strategies to change behavior. Individuals in the C stage utilize these processes more than those in the PC stage, and utilize the experiential processes more than the behavioral processes (DiClemente et al., 1995; Fava et al., 1995; Prochaska, DiClemente, & Norcross, 1992). Five out of six Processes of Change for Smoking that were found to impact smoking outcome through the Pros of Smoking were experiential processes, and this finding provides longitudinal evidence for the validity of this TTM prediction. Counter Conditioning, which represents one of the behavioral processes of change, also demonstrated evidence of statistical mediation through the Pros of Smoking. This

finding suggests that some participants in C would benefit from interventions that emphasized some behavioral strategies to quit smoking.

Models with the Cons of Smoking as Mediator

The Cons of Smoking represent negative or unappealing aspects of cigarette smoking and their importance to the smoker (Velicer et al., 1985). The Cons were hypothesized as a potential mediator because of empirical evidence that the Cons of Smoking typically increase as a smoker makes progress to quitting smoking (Hall & Rossi, 2008). For participants starting intervention in the C stage, three Processes of Change for Smoking were found to demonstrate evidence of statistical mediation through the Cons of Smoking. They were Environmental Reevaluation, Self-Reevaluation, and Social Liberation.

For the Cons of Smoking, all three Processes of Change associated with evidence of statistical mediation (Environmental Reevaluation, Self-Reevaluation, and Social Liberation) were experiential processes, which provides support for the TTM prediction that experiential processes are more important than behavioral processes for individuals in the earlier stages. Two additional processes (Self Liberation and Stimulus Control) were found to have statistical significance for both regression paths in the mediation pathway, but were found to have asymmetric confidence intervals that included zero. These two processes, Self Liberation and Stimulus Control, are both behavioral processes. While they do not show strong evidence of statistical mediation, based on the presence of zeros in confidence intervals, they may still have some value to changing the smoking outcome through the Cons of Smoking. However, the evidence to focus on experiential processes is far greater.

Models with Situational Temptations as Mediator

Situational Temptations to Smoke represent situations where smokers would feel tempted to smoke (Velicer et al., 1990). Situational Temptations were hypothesized as a potential mediator because of evidence that temptations typically decrease as a smoker makes progress to quitting smoking (Blissmer et al., 2010; Prochaska et al., 1985; Prochaska et al., 1991). For

participants starting intervention in the C stage, three Processes of Change for Smoking were found to demonstrate evidence of statistical mediation through the Situational Temptations to Smoke. They were Self-Revaluation, Counter Conditioning, and Stimulus Control.

Unlike the patterns of statistical mediation found with the Pros of Smoking and the Cons of Smoking, two out of three of the processes that were associated with mediation (Counter Conditioning and Stimulus Control) were behavioral processes. These results were not expected, based on TTM predictions for individuals in C, and they provide important insight into how behavioral strategies can influence smoking through Situational Temptations. Counter Conditioning and Stimulus Control appear to represent important strategies to manage temptations to smoke for contemplators. The relation among Counter Conditioning and Situational Temptations, however, may be strongly influenced by the fact that one of the items for Counter Conditioning includes the word tempted: "When I am tempted to smoke I think about something else." This could explain the strength of the evidence of mediation with Counter Conditioning through Situational Temptations.

Overall Patterns

All five separate studies that were combined to create the sample for the present study were successful in decreasing smoking rates. By breaking apart the intervention components and investigating statistical mediation over time, these studies have essentially undergone a quantitative dissection to reveal what intervention components drove the outcomes. The Pros of Smoking, Cons of Smoking, and Situational Temptations to Smoke all demonstrated evidence of statistical mediation with multiple Processes of Change for Smoking. The combinations of variables that demonstrated statistical mediation provide valuable insight into what drove the smoking outcomes.

Different combinations of independent variables and mediators produced mediation effects of different magnitudes. Effect sizes quantify the strength of the mediational relations and are pivotal to interpreting the overall evidence for mediation. Five Processes of Change for

Smoking demonstrated medium or large mediation effects, based on standardized paths (product of standardized paths ≥0.06 for medium, ≥0.13 for large). These five processes, from largest to smallest effects, were: Counter Conditioning, Consciousness Raising, Self-Reevaluation, Dramatic Relief, and Social Liberation. Counter Conditioning, one of the behavioral processes of change, involves replacing smoking with other behaviors. The results of the present study suggest that this strategy is important, even to smokers in early stages such as C. Consciousness Raising involves thinking about quitting smoking and the benefits of quitting smoking. At C, many individuals are already thinking about their smoking and further increasing Consciousness Raising will only help them become more aware their smoking behavior. Self-Reevaluation involves individuals feeling upset or disappointed in themselves for their smoking. Such negative feelings seem to be related to the higher Cons of Smoking reported by individuals in the C stage (Hall & Rossi, 2008; Velicer et al., 1985). Social Liberation involves the consideration of the advantages nonsmokers have in society.

In addition to evaluating the magnitude of the mediated effects, the Processes of Change that demonstrated mediation through multiple mediators should be considered important. These processes included Environmental Reevaluation (pros and temptations), Social Liberation (pros and cons), Self Reevaluation (pros, cons, and temptations), and Counter Conditioning (pros and temptations). Three out of four of these were already identified as being important based on their effect sizes. Environmental Reevaluation involves thinking about the polluting effects of smoking and the effects of smoking on the smoker's social environment. These findings suggest that interventions that emphasize consideration of how smoking impacts others, as well as the environment, will influence the smoking behavior of individuals that begin an intervention in C. Stimulus Control also demonstrated evidence of statistical mediation, but it demonstrated small effects through only one mediator; thus, results from these single mediator models suggest Stimulus Control is not among the most important processes at C.

The two paths that made up the mediation pathway, process at baseline to mediator at 12 months (a_1) and mediator at 12 months to smoking outcome at 24 months (b_2), were the focus of the present study, but there were many other paths that revealed important information about statistical mediation. Two additional paths that were important to mediation were the two direct effects, process at baseline to smoking outcome at 12 months (c'_1) and process at 12 months to smoking outcome at 24 months (c'_2). These paths describe the relations from the independent variables to the dependent variables, adjusted for the effects of the mediators. In statistical mediation models, effective mediators should result in comparatively small direct effects, and in the present study, the direct effects were consistently very small. Examples of these relations are included in Figures 2.2 through 2.8.

Limitations

The use of secondary data represents the biggest limitation to the present study. Limitations from the original studies impacted the statistical mediation analyses in a number of ways. First, the diversity of the sample was suboptimal; each of the five studies was primarily white, and the combined sample was nearly 92% white. A substantially more diverse sample, with more participants of different races and different ethnicities, would greatly improve the validity of these statistical mediation models. Additionally, a truly international sample would further increase the generalizability of the results, and the results would better represent the true underlying mechanisms of smoking behavior change.

Second, the details of the tailored interventions produced some limitations. The five original studies that comprised the combined sample all utilized stage-matched tailoring; participants in different stages received feedback that emphasized certain processes of change. For example, participants in PC typically received feedback that highlighted experiential processes of change, such as Consciousness Raising, Environmental Reevaluation, and Self-Reevaluation. Since participants did not receive an equal amount of feedback for each of the ten processes, the tailoring may have impacted process use differentially. Determining the extent to

which the tailoring influenced the relations among the processes and the mediators was impossible because control groups could not be included in the analyses. All analyses were conducted on participants that were in treatment groups, and the lack of control groups created multiple important limitations. Analyses could not be performed because the processes of change were not assessed in the control conditions of the original studies (to reduce contamination due to measurement). Comparisons among the treatment and control groups would have revealed important intervention effects as well as additional insight into the mechanisms of smoking behavior change. If the mediation relations described in the present study truly represent mechanisms of behavior change for smoking, control groups would demonstrate similar relations, but with lower magnitudes, as TTM interventions are thought to accelerate naturalistic processes of behavior change (Prochaska & Velicer, 1997; Velicer et al., 2000; Velicer et al., 2006b). Additionally, evidence for causality was limited due to the lack of data from control groups; comparing data from randomized treatment and control conditions would greatly enhance evidence of causal relations.

Third, measurement issues from the original studies resulted in some limitations. The lack of data for the processes of change in control groups, as discussed above, was the biggest limitation. Another limitation was that the short forms of all measures were utilized. For example, each of the processes of change was measured by two items. In the intervention studies, this was necessary to prevent the assessments from being unreasonably long. For the present study, measures with more items would have been very beneficial. Coefficient alpha values for many measures, including the processes of change, pros, and cons were often low (but still within an acceptable range); internal consistency for each measure would be improved with additional items. Additional items for measures may have also improved the predictive power of constructs. Relations among processes of change and mediators, as well as processes of change and smoking outcomes, were typically smaller in magnitude than the relations among mediators and smoking outcomes. This finding may be partially explained by the two-item scales for the processes.

Additional items for each of the processes could increase the magnitude of relations, and this could result in more evidence for statistical mediation.

Smoking outcome was an important component of all mediation models and was associated with some limitations. Unlike other constructs in the present study (e.g., Consciousness Raising, Cons of Smoking), which were previously validated in past studies, the smoking outcome was specifically developed to perform statistical mediation models for smoking. The two items that measured the latent variable for smoking outcome, time to first cigarette and cigarettes per day, have been used extremely often in smoking intervention studies, but are typically not combined as a latent variable. Thus, the measure could benefit from more vigorous psychometric testing in the future. As with the other scales, the smoking outcome would be strengthened by additional items. One type of item that would be particularly beneficial for the smoking outcome would be an item that reflected stage progression. Someone in C may not change very much on these overt behaviors, but may progress to PR, which predicts future change (Blissmer et al., 2010). Regardless, the smoking outcome variable in the present study (as well as a separate study that evaluated mediation with PC) performed very well, and correlated highly with Situational Temptations to Smoke, which has been used in the past as a smoking outcome variable (Velicer et al., 1996).

Fourth, timing issues related to both measurement and intervention were also limitations. At least three time points were necessary to run the longitudinal mediation models; baseline, 12 months, and 24 months were selected because all original five studies had full assessments at these time points. However, in all of these studies the intervention was complete by the 12-month time point. Thus, the most dramatic changes may have occurred between baseline and 12 months, but these could not be fully captured in the mediation models. The changes from 12 months to 24 months involved the lasting effects of the intervention. The mediation models in the present study described changes over a wide time frame, and they would be improved with additional time points.

All of these areas of limitations could be addressed with a study specifically designed to test mediational hypotheses. An ideal TTM-tailored intervention study to test mediation would (1) recruit a large, diverse sample; (2) collect data for all TTM constructs for both treatment and control groups; (3) utilize scales for TTM constructs that had more than two items each and include extra items to assess smoking behavior; and (4) perform full assessments (at least) every six months. With the data produced by such a study, the resulting mediation models would provide very compelling evidence of the mechanisms of smoking behavior change.

An important limitation of the present study, likely unrelated to the use of secondary data, involved the signs of the regression paths in the mediation models. In many instances, the signs of regression paths were opposite from what was expected. The longitudinal regression paths in particular had some unusual patterns. Notably, the path from the mediator at 12 months to the smoking outcome at 24 months (b_2) in the mediation pathway was consistently found to be negative. This negative path is challenging to interpret. For example, consider the Pros of Smoking; a negative b_2 coefficient would suggest that a decrease in the Pros of Smoking at 12 months predicts an increase in smoking at 24 months, which is incorrect. In fact, the Pros of Smoking at 12 months were positively, not negatively, correlated with the smoking outcome at 24 months. Paths with unexpectedly negative signs were also found in the evaluation of statistical mediation models at PC (manuscript 1 in the present series of studies). This unexpected finding suggests the presence of suppressor effects (Kline, 2005; MacKinnon, 2008; Velicer, 1978). Suppressor effects are common in longitudinal structural equation models and are even more common when latent variables are involved (Maassen & Bakker, 2001).

The unexpectedly negative b_2 paths likely represent examples of negative suppression, where the signs are reversed due to the presence of other, stronger positive predictors of smoking outcome at 24 months. For the b_2 path from the Pros of Smoking at 12 months to smoking at 24 months, these other predictors included smoking outcome at 12 months and the Pros of Smoking at 24 months. Further evidence of suppression was found through modification of the models.

When one of the strong predictors of smoking outcome at 24 months was deleted from the model (either the smoking outcome at 12 months or the Pros of Smoking at 24 months), the sign of the longitudinal mediation path b_2 flipped from negative to positive. This suggested that b_2 was negative simply because of the other predictors. Due to suppression effects, the signs of regression paths need to be interpreted with caution. Instead, effect sizes should be the emphasis of interpretation. The magnitude of each regression path, as described by the standardized coefficients, is very important. The effect size of the overall mediation pathway, calculated from the product of the standardized coefficients, is also more important to describing mediation than the signs of any individual paths.

In addition to the b_2 paths being distorted by suppressor effects, the a_1 paths need to be interpreted with caution for some of the behavioral processes. In particular, Counter Conditioning and Stimulus Control were found to have positive coefficient from process use at baseline to Pros of Smoking and Situational Temptations at 12 months. This suggests that increasing the use of these processes of change predicts higher Pros of Smoking and higher temptations at 12 months, which is an opposite pattern from the other processes. While these unexpected results may be the result of suppressor effects, these patterns may also represent relations that were simply not anticipated. For example, increased use of the behavioral processes may be associated with increased Situational Temptations 12 months later because such processes represent strategies to cope with strong temptations, and temptations do not decrease until late stages (Blissmer et al., 2010; Prochaska et al., 1985; Prochaska et al., 1991; Velicer et al., 1996). Future studies looking at relapse, with smokers in the action or maintenance stage for smoking, could help explain this finding.

Future Directions for Analysis

As described above, some of the processes showed mediation through multiple mediators. These combinations can be investigated with multiple mediator models. In addition to multiple mediator models, many combinations of processes showed mediation through the same

mediator, and these multiple process models can also be investigated. Separate studies (manuscripts 4 and 5 in the present series of studies) will evaluate both multiple mediator and multiple process models. Creating models with additional independent and mediator variables will provide a more comprehensive investigation of what is driving the intervention outcomes.

An important validity check for the statistical mediation models developed in the present study will be whether the estimates are consistent across subsamples. For example, different age groups may demonstrate different patterns within the single mediator models. In the framework of SEM, multiple subsamples can be compared simultaneously with factorial invariance procedures (Meredith, 1993). A separate study (manuscript 6 in the present series of studies) will evaluate factorial invariance across a series of subgroup variables, including age, education level, gender, race, and original study.

Conclusions

For participants at C, the Pros of Smoking, Cons of Smoking, and Situational Temptations were found to be important mediators for smoking behavior. Consciousness Raising, Dramatic Relief, Environmental Reevaluation, Self-Reevaluation, Social Liberation, and Counter Conditioning were crucial for driving changes in these mediators. Increasing basic knowledge of the mechanisms that underlie smoking cessation directly relates to increasing understanding of how these mechanisms relate to successful interventions. New interventions can be tailored to focus on the variables that are most likely to have the biggest effects on behavioral outcomes. Modern, computerized interventions will be able to adapt to make intervention contacts as relevant as possible by tailoring to individuals to focus on which behavioral mechanisms are the most important to changing behavior. Future improvement and refinement of statistical mediation models will directly lead to improvement and refinement of smoking cessation interventions, and development of more effective interventions for smoking will address a major concern for public health.

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Table 2.1. Average means with standard deviations for participants at C at baseline for independent variables (ten Processes of Change for Smoking Cessation), mediators (Pros, Cons, Situational Temptations), and dependent variables (smoking outcome) at the baseline, 12-month, and 24-month time points

Variable	Baseline		12 Months		24 Months	
	Mean	SD	Mean	SD	Mean	SD
Independent Variables						
Experiential processes						
Consciousness Raising	3.245	1.025	3.067	1.051	3.025	1.059
Dramatic Relief	2.823	1.116	2.863	1.099	2.897	1.121
Environmental Reevaluation	2.865	1.344	2.678	1.247	2.759	1.244
Self-Reevaluation	3.272	1.207	3.221	1.217	3.118	1.274
Social Liberation	4.028	0.947	4.001	0.944	4.051	0.958
Behavioral Processes						
Counter Conditioning	2.385	0.959	2.633	1.000	2.648	1.060
Helping Relationships	2.686	1.332	2.674	1.308	2.748	1.330
Reinforcement Management	2.204	1.276	2.258	1.237	2.337	1.295
Self Liberation	3.342	1.103	3.360	1.133	3.333	1.170
Stimulus Control	1.684	0.949	1.920	1.041	2.012	1.063
Mediators						
Pros	2.569	0.971	2.472	1.030	2.412	1.056
Cons	3.329	0.988	3.300	1.141	3.320	1.146
Situational Temptations	3.398	0.721	3.127	0.941	3.005	1.052
Dependent Variables						
Smoking Outcome	3.275	0.801	2.922	1.161	2.775	1.207

All variables on a 1-5 scale; see appendix for additional materials on the scales

Table 2.2. Fit indices at C for all mediation models, complete case analysis

Model	N	χ^2	(df)	NFI	CFI	RMSEA	(90% RMSEA)
Mediator: Pros of Smoking							
Consciousness Raising	487	214.738	(149)	0.949	0.984	0.030	(0.020, 0.038)
Dramatic Relief	488	220.183	(149)	0.952	0.984	0.031	(0.022, 0.040)
Environmental Reevaluation	488	234.221	(149)	0.958	0.984	0.034	(0.026, 0.042)
Self-Reevaluation	487	197.969	(149)	0.959	0.989	0.026	(0.015, 0.035)
Social Liberation	487	194.216	(149)	0.952	0.988	0.025	(0.014, 0.034)
Counter Conditioning	489	266.526	(149)	0.937	0.971	0.040	(0.032, 0.048)
Helping Relationships	484	226.256	(149)	0.955	0.984	0.033	(0.024, 0.041)
Reinforcement Management	485	219.153	(149)	0.956	0.986	0.031	(0.021, 0.039)
Self Liberation	489	216.772	(149)	0.952	0.984	0.031	(0.021, 0.039)
Stimulus Control	486	223.205	(149)	0.950	0.982	0.032	(0.023, 0.040)
Mediator: Cons of Smoking							
Consciousness Raising	485	255.383	(149)	0.937	0.972	0.038	(0.030, 0.046)
Dramatic Relief	486	252.679	(149)	0.943	0.976	0.038	(0.030, 0.046)
Environmental Reevaluation	486	217.328	(149)	0.959	0.987	0.031	(0.021, 0.039)
Self-Reevaluation	485	278.339	(149)	0.942	0.960	0.042	(0.035, 0.050)
Social Liberation	485	211.085	(149)	0.946	0.983	0.029	(0.020, 0.038)
Counter Conditioning	488	343.860	(149)	0.913	0.948	0.052	(0.044, 0.059)
Helping Relationships	483	231.729	(149)	0.951	0.982	0.034	(0.025, 0.042)
Reinforcement Management	483	250.929	(149)	0.948	0.978	0.038	(0.029, 0.046)
Self Liberation	487	273.144	(149)	0.936	0.970	0.041	(0.033, 0.049)
Stimulus Control	484	272.793	(149)	0.935	0.969	0.041	(0.034, 0.049)
Mediator: Situational Temptations							
Consciousness Raising	491	239.520	(149)	0.957	0.983	0.035	(0.027, 0.043)
Dramatic Relief	492	273.210	(149)	0.955	0.979	0.041	(0.033, 0.049)
Environmental Reevaluation	492	246.179	(149)	0.965	0.986	0.036	(0.028, 0.044)
Self-Reevaluation	491	268.233	(149)	0.958	0.981	0.040	(0.032, 0.048)
Social Liberation	491	245.893	(149)	0.956	0.982	0.036	(0.028, 0.044)
Counter Conditioning	493	336.174	(149)	0.942	0.967	0.050	(0.043, 0.057)
Helping Relationships	488	518.002	(149)	0.923	0.944	0.071	(0.064, 0.077)
Reinforcement Management	489	266.705	(149)	0.959	0.981	0.040	(0.032, 0.048)
Self Liberation	493	254.799	(149)	0.957	0.982	0.038	(0.030, 0.046)
Stimulus Control	491	248.024	(149)	0.958	0.983	0.037	(0.029, 0.045)

Table 2.3. Fit indices at C for all mediation models, missing data estimated with ML

Model	N	χ^2	(df)	NFI	CFI	RMSEA	(90% RMSEA)
Mediator: Pros of Smoking							
Consciousness Raising	1243	230.677	(149)	0.997	1.000	0.000	-
Dramatic Relief	1243	216.197	(149)	0.998	1.000	0.000	-
Environmental Reevaluation	1243	228.777	(149)	1.000	1.000	0.000	-
Self-Reevaluation	1243	220.513	(149)	0.998	1.000	0.000	-
Social Liberation	1243	219.339	(149)	0.999	1.000	0.000	-
Counter Conditioning	1243	339.885	(149)	0.996	1.000	0.000	-
Helping Relationships	1243	247.219	(149)	0.999	1.000	0.000	-
Reinforcement Management	1243	265.101	(149)	0.999	1.000	0.000	-
Self Liberation	1243	258.305	(149)	0.995	1.000	0.000	-
Stimulus Control	1243	256.058	(149)	0.999	1.000	0.000	-
Mediator: Cons of Smoking							
Consciousness Raising	1243	544.651	(149)	0.945	0.969	0.031	(0.027, 0.036)
Dramatic Relief	1243	261.074	(149)	0.993	1.000	0.000	-
Environmental Reevaluation	1243	264.808	(149)	0.999	1.000	0.000	-
Self-Reevaluation	1243	348.421	(149)	0.991	1.000	0.000	-
Social Liberation	1243	495.552	(149)	0.950	0.975	0.028	(0.023, 0.032)
Counter Conditioning	1243	441.162	(149)	1.000	1.000	0.000	-
Helping Relationships	1243	532.398	(149)	0.960	0.979	0.028	(0.024, 0.033)
Reinforcement Management	1243	566.866	(149)	0.957	0.977	0.030	(0.025, 0.034)
Self Liberation	1243	314.533	(149)	0.991	1.000	0.000	-
Stimulus Control	1243	341.261	(149)	0.991	1.000	0.000	-
Mediator: Situational Temptations							
Consciousness Raising	1243	403.022	(149)	0.984	1.000	0.000	(0.000, 0.010)
Dramatic Relief	1243	393.412	(149)	0.985	1.000	0.000	(0.000, 0.011)
Environmental Reevaluation	1243	410.308	(149)	0.987	1.000	0.000	(0.000, 0.009)
Self-Reevaluation	1243	413.577	(149)	0.983	0.999	0.007	(0.000, 0.015)
Social Liberation	1243	396.931	(149)	0.981	0.999	0.006	(0.000, 0.015)
Counter Conditioning	1243	551.500	(149)	0.966	0.983	0.028	(0.023, 0.032)
Helping Relationships	1243	415.636	(149)	0.987	1.000	0.000	(0.000, 0.006)
Reinforcement Management	1243	418.271	(149)	0.990	1.000	0.000	-
Self Liberation	1243	420.058	(149)	0.981	0.998	0.009	(0.000, 0.017)
Stimulus Control	1243	434.185	(149)	0.980	0.997	0.011	(0.000, 0.018)

- Lower confidence limit negative, interval not calculated

Table 2.4. Unstandardized (with standard errors) and standardized longitudinal regression paths describing the mediation pathway; Processes of Change at baseline to mediator at 12 months (a_1) and mediator at 12 months to smoking outcome at 24 months (b_2)

Model	a_1	s.e.	Std. a_1	b_2	s.e.	Std. b_2
Mediator: Pros of Smoking						
Consciousness Raising	-0.378*	0.136	-0.251	-0.405*	0.093	-0.360
Dramatic Relief	-0.309*	0.124	-0.212	-0.405*	0.094	-0.348
Environmental Reevaluation	-0.160*	0.072	-0.110	-0.419*	0.095	-0.362
Self-Reevaluation	-0.339*	0.111	-0.217	-0.391*	0.090	-0.361
Social Liberation	-0.269*	0.099	-0.173	-0.384*	0.088	-0.356
Counter Conditioning	0.481*	0.154	0.226	-0.419*	0.108	-0.490
Helping Relationships	0.022	0.073	0.015	-0.426*	0.096	-0.372
Reinforcement Management	-0.042	0.075	-0.029	-0.388*	0.092	-0.336
Self Liberation	0.015	0.081	0.010	-0.427*	0.096	-0.380
Stimulus Control	0.160	0.082	0.103	-0.424*	0.098	-0.383
Mediator: Cons of Smoking						
Consciousness Raising	-0.380	0.208	-0.229	-0.226*	0.085	-0.220
Dramatic Relief	-0.752*	0.214	-0.477	-0.083	0.061	-0.085
Environmental Reevaluation	-0.254*	0.085	-0.181	-0.148*	0.062	-0.137
Self-Reevaluation	-0.531*	0.190	-0.331	-0.157*	0.065	-0.165
Social Liberation	-0.477*	0.182	-0.294	-0.226*	0.079	-0.214
Counter Conditioning	-0.265	0.172	-0.199	-0.130	0.071	-0.112
Helping Relationships	-0.084	0.077	-0.064	-0.260*	0.079	-0.201
Reinforcement Management	-0.104	0.082	-0.080	-0.247*	0.080	-0.188
Self Liberation	-0.173*	0.084	-0.130	-0.159*	0.064	-0.141
Stimulus Control	-0.235*	0.095	-0.175	-0.132*	0.065	-0.117
Mediator: Situational Temptations						
Consciousness Raising	-0.148	0.092	-0.122	-0.585*	0.130	-0.345
Dramatic Relief	-0.093	0.094	-0.078	-0.566*	0.131	-0.329
Environmental Reevaluation	-0.100	0.059	-0.083	-0.595*	0.131	-0.347
Self-Reevaluation	-0.322*	0.091	-0.255	-0.533*	0.125	-0.331
Social Liberation	-0.126	0.072	-0.102	-0.574*	0.127	-0.343
Counter Conditioning	0.179*	0.086	0.131	-0.624*	0.131	-0.403
Helping Relationships	-0.028	0.059	-0.023	-0.602*	0.130	-0.356
Reinforcement Management	-0.020	0.064	-0.016	-0.568*	0.129	-0.332
Self Liberation	0.068	0.066	0.055	-0.589*	0.130	-0.349
Stimulus Control	0.200*	0.067	0.162	-0.541*	0.129	-0.318

** $p < 0.05$*

Table 2.5. Products, standard errors, 95% asymmetric confidence limits, and products of standardized coefficients for the Processes of Change that demonstrated statistical significance for both a_1 and b_1 paths

Model	Product of a_1 and b_1	s.e.	(95% Product)	Product of Std. a_1 and b_1
Mediator: Pros of Smoking				
Consciousness Raising	0.153	0.067	(0.039, 0.299)	0.090
Dramatic Relief	0.125	0.059	(0.024, 0.255)	0.074
Environmental Reevaluation	0.067	0.034	(0.007, 0.142)	0.040
Self-Reevaluation	0.133	0.054	(0.040, 0.251)	0.078
Social Liberation	0.103	0.046	(0.025, 0.203)	0.062
Counter Conditioning	-0.202	0.084	(-0.388, -0.060)	-0.111
Mediator: Cons of Smoking				
Environmental Reevaluation	0.038	0.021	(0.004, 0.085)	0.025
Self-Reevaluation	0.083	0.047	(0.009, 0.191)	0.055
Social Liberation	0.108	0.058	(0.016, 0.239)	0.063
Self Liberation	0.028	0.018	(0.000, 0.070)	0.018
Stimulus Control	0.031	0.021	(0.000, 0.079)	0.020
Mediator: Situational Temptations				
Self-Reevaluation	0.172	0.064	(0.062, 0.312)	0.084
Counter Conditioning	-0.112	0.060	(-0.240, -0.006)	-0.053
Stimulus Control	-0.108	0.045	(-0.208, -0.031)	-0.052

Figure 2.1. Autoregressive mediation model II template, with Processes of Change (P) as independent variables, mediating variables (M) as mediators, and smoking outcome (Smoking) as dependent variables; at the baseline, 12-month, and 24-month time points

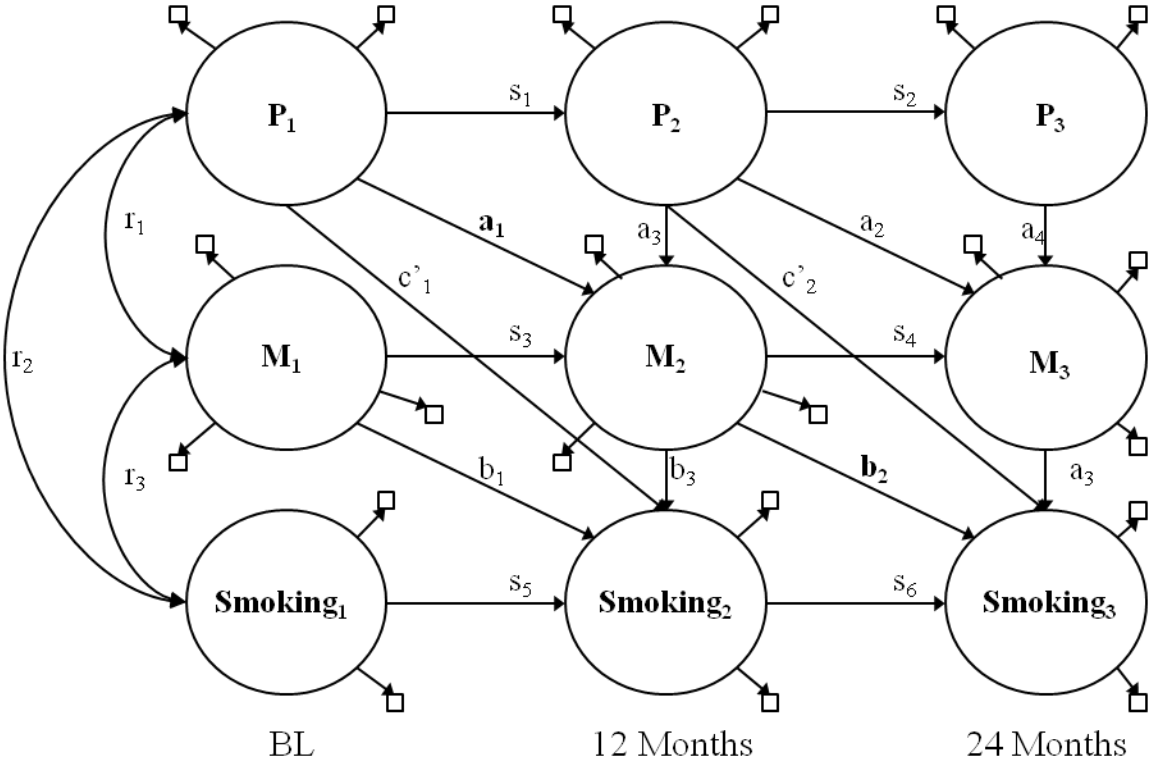
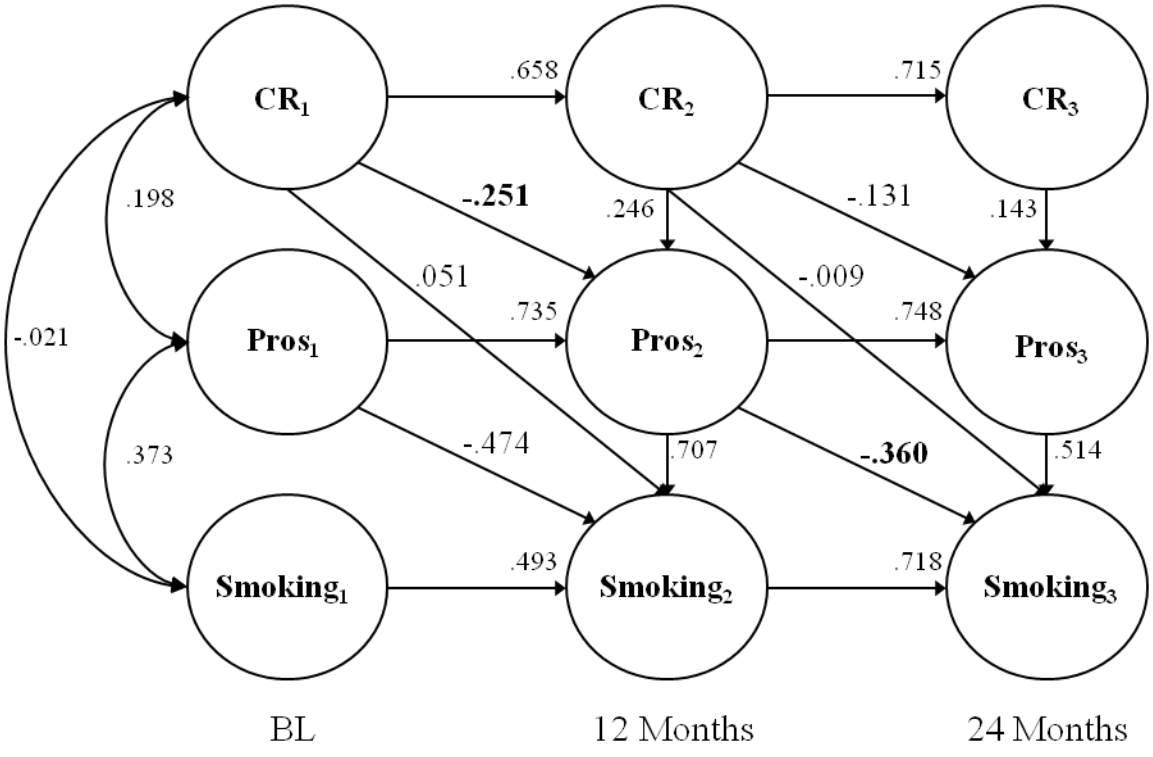
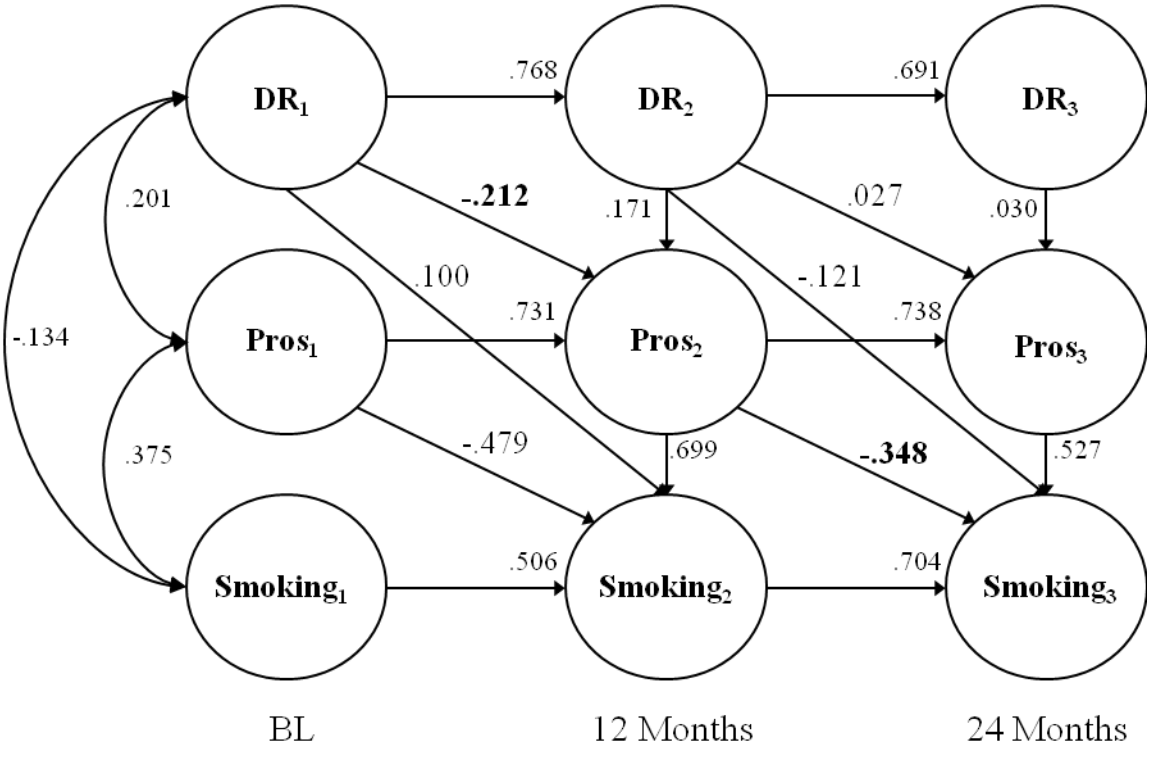


Figure 2.2. Single mediator model at C with Consciousness Raising (CR) as independent variables, Pros of Smoking (Pros) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



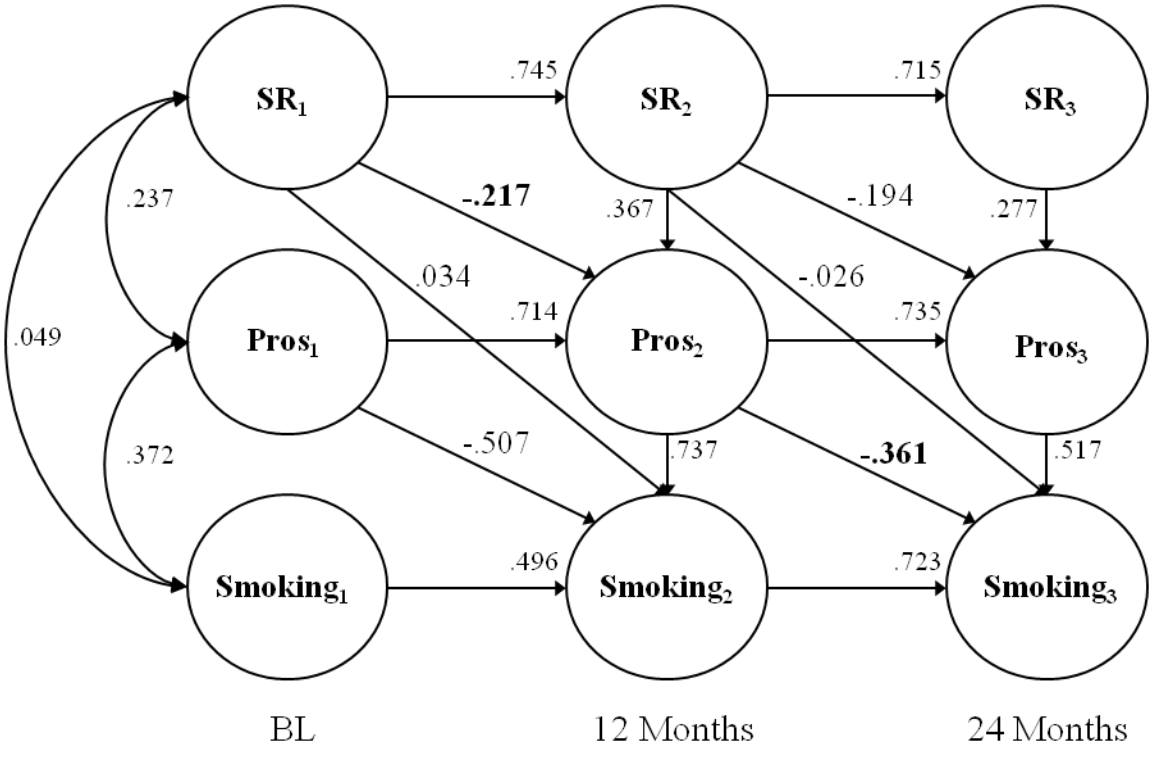
Product of standardized a_1 and b_2 paths = .090

Figure 2.3. Single mediator model at C with Dramatic Relief (DR) as independent variables, Pros of Smoking (Pros) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



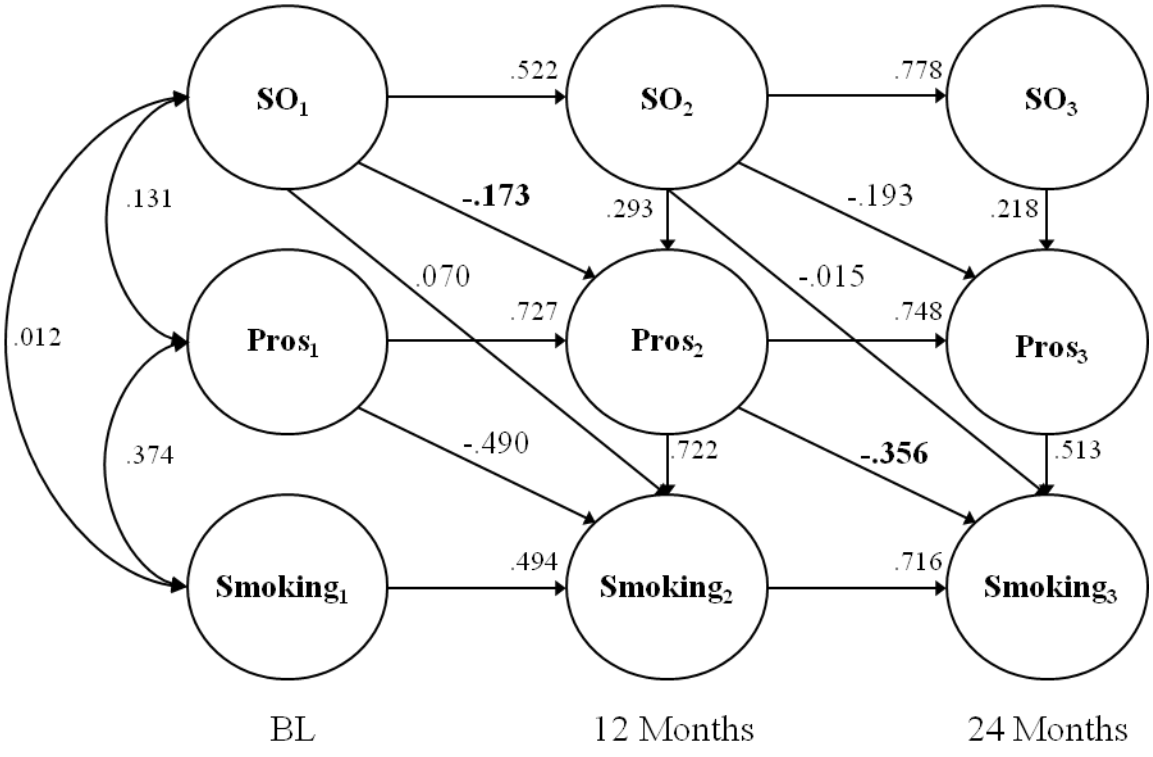
Product of standardized a_1 and b_2 paths = .074

Figure 2.4. Single mediator model at C with Self-Reevaluation (SR) as independent variables, Pros of Smoking (Pros) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



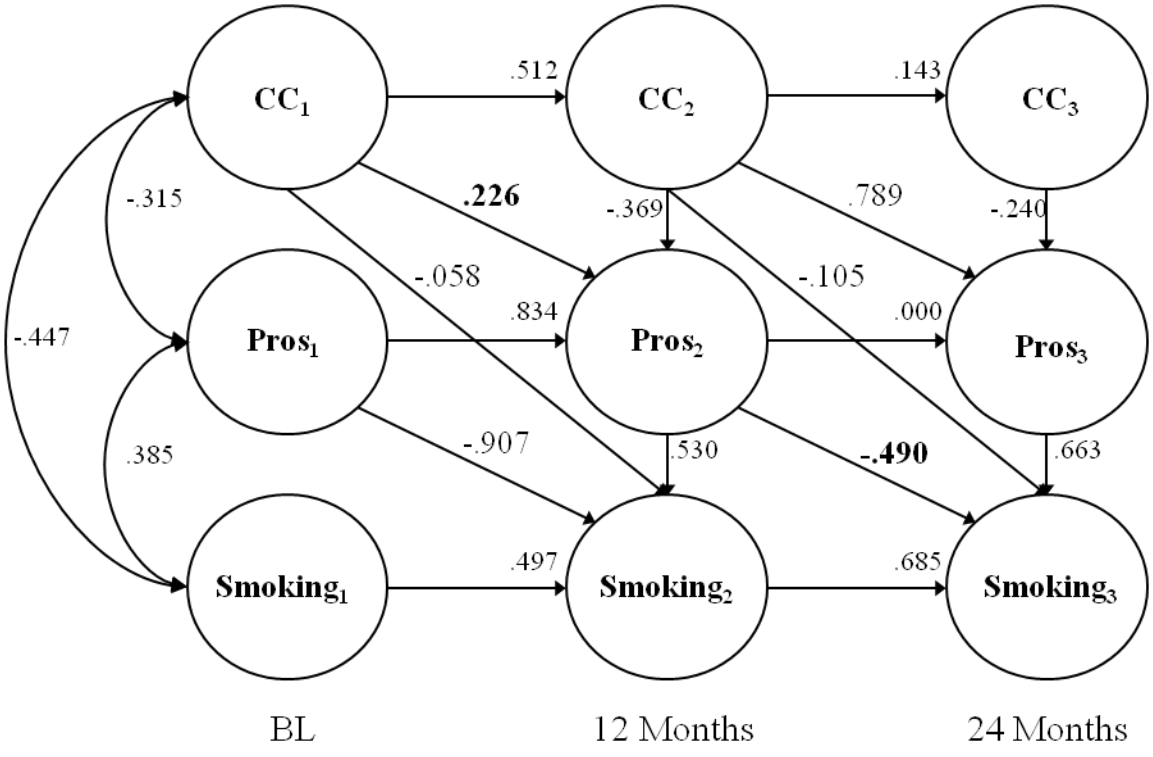
Product of standardized a_1 and b_2 paths = .078

Figure 2.5. Single mediator model at C with Social Liberation (SO) as independent variables, Pros of Smoking (Pros) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



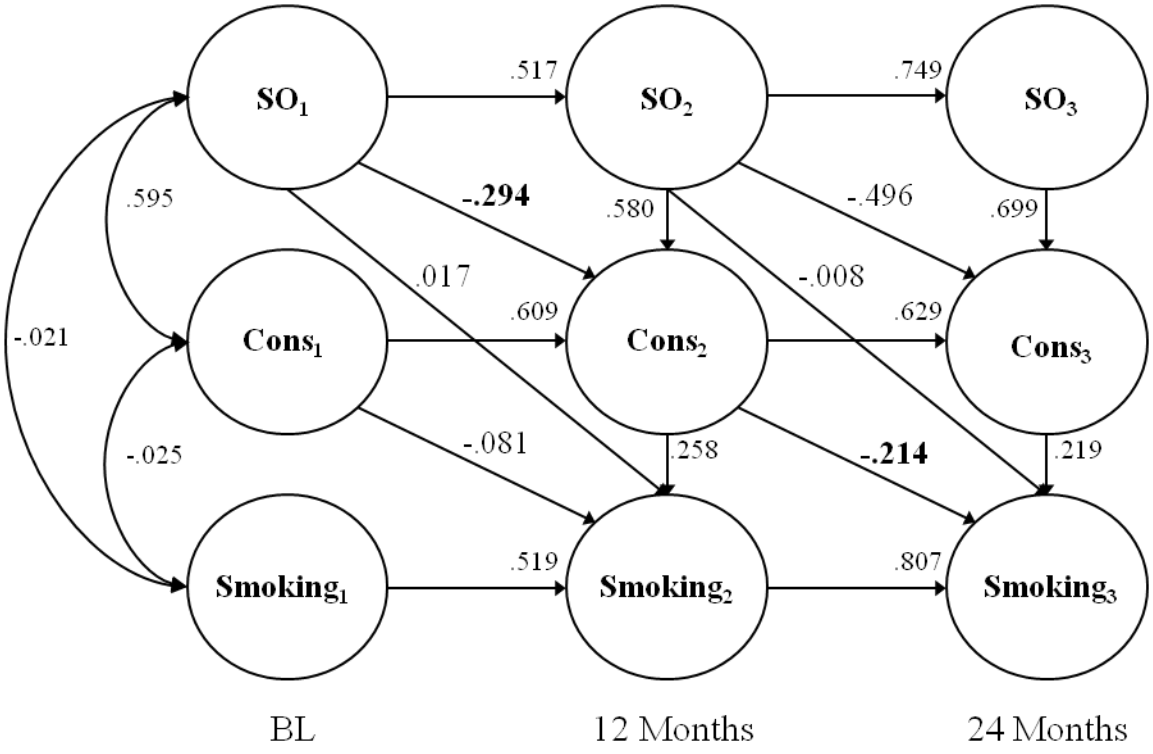
Product of standardized a_1 and b_2 paths = .062

Figure 2.6. Single mediator model at C with Counter Conditioning (CC) as independent variables, Pros of Smoking (Pros) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



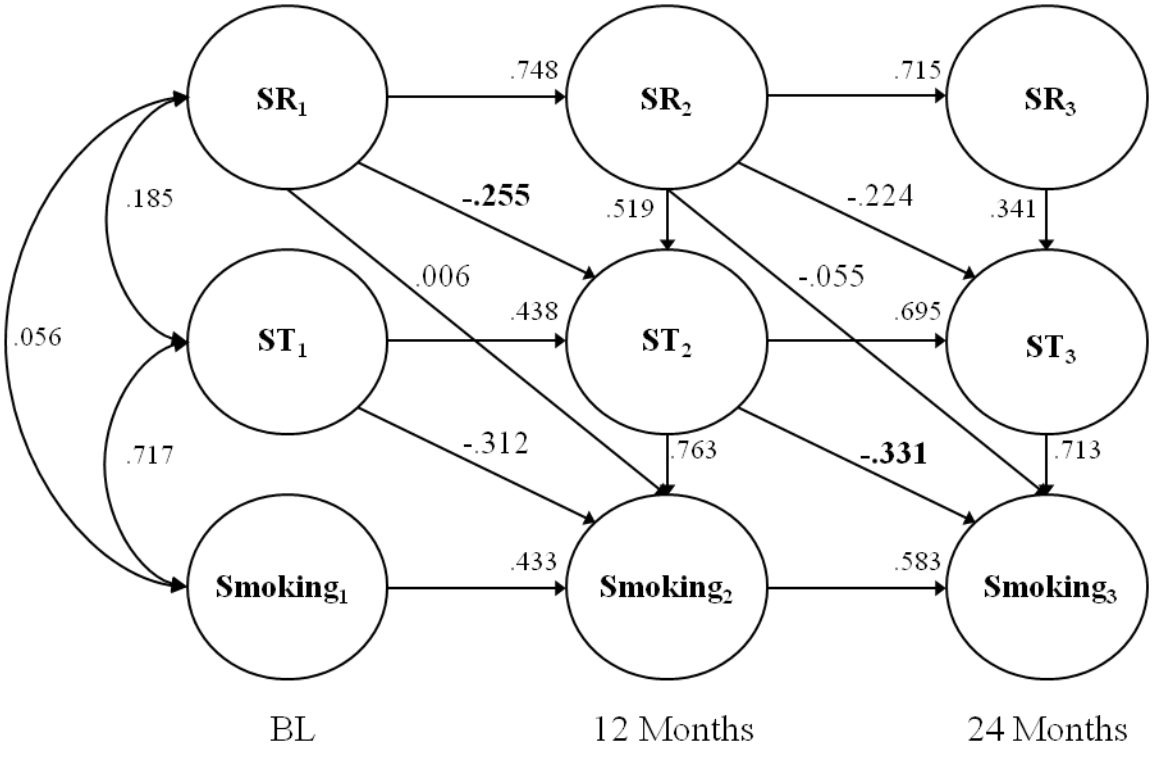
Product of standardized a_1 and b_2 paths = -.111

Figure 2.7. Single mediator model at C with Social Liberation (SO) as independent variables, Cons of Smoking (Cons) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



Product of standardized a_1 and b_2 paths = .063

Figure 2.8. Single mediator model at C with Self-Reevaluation (SR) as independent variables, Situational Temptations (ST) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



Product of standardized a_1 and b_2 paths = .084

MANUSCRIPT 3

Investigating the Mechanisms of Smoking Behavior Change: Single Mediator Models for Smokers in the Preparation Stage

Manuscript to be submitted to *Prevention Science*

Abstract

Investigating and quantifying the mechanisms that underlie behavior change is essential to understanding what drives effective interventions. While many population-based smoking interventions have a theoretical framework, the mechanisms that impact behavior change during the intervention are rarely explored empirically. Better understanding variables that explain changes in smoking behavior can provide a basis for more direct and effective interventions. The present study combined data (N = 499) from five randomized Transtheoretical Model (TTM)-tailored intervention studies. Statistical mediation analysis with autoregressive, three-wave models was utilized to investigate changes in behavioral variables across three time points (baseline, 12 months, and 24 months) for participants in the preparation stage (PR; smokers that are planning to quit in the next month and have had at least one successful 24-hour quit attempt in the past year) at baseline. The ten Processes of Change for Smoking were used as independent variables, Pros of Smoking, Cons of Smoking, and Situational Temptations to Smoke were used as mediators, and a behavioral smoking outcome was used as the dependent variable for a total of 30 separate mediation models. Models were assessed with structural equation modeling, and all demonstrated very good fit (CFI > 0.95; RMSEA < 0.05). The Pros and Cons of Smoking did not demonstrate evidence of statistical mediation with any of the Processes of Change. Self-Reevaluation demonstrated evidence of statistical mediation through Situational Temptations to Smoke. Development and refinement of statistical mediation models to assess the mechanisms of behavior change are crucial to enhancing basic knowledge and informing intervention efforts.

Keywords: Statistical Mediation Analysis, Smoking Cessation, Transtheoretical Model, Preparation Stage

Investigating the Mechanisms of Smoking Behavior Change:

Single Mediator Models for Smokers in the Preparation Stage

Mechanisms of behavior change explain how and why behavior change occurs. Better understanding behavioral mechanisms necessitates better understanding variables that account for observed changes in behavior. Despite the importance of mechanisms of behavior change, knowledge about these mechanisms is presently very limited (NIH, 2009; 2012). Investigating and quantifying such mechanisms that underlie behavior change is essential to understanding what drives effective interventions. Many interventions follow a "black-box" approach, where the intervention components are related to the intervention outcomes, with no empirical investigation of what drives these outcomes. Many content areas would greatly benefit from a comprehensive investigation of the mechanisms that drive behavior change.

Due to its extreme consequences, cigarette smoking represents a key health behavior that needs to be better understood. Despite decades of prevention and intervention efforts, smoking remains a critical concern for public health in the United States. Approximately 19% of U.S. adults are smokers, and while smoking prevalence rates have decreased from approximately 42% in 1965, this decrease seems to be slowing (Centers for Disease Control [CDC], 2011a; 2011b; 2012). An estimated 443,000 adults die from smoking-related illnesses every year, and smoking is estimated to cost the United States $96 billion and $97 billion in direct medical expenses and lost productivity, respectively (CDC, 2008; 2012). An older estimate suggests that of all the people alive in the world today, 500,000,000 are expected to die from tobacco use (Peto & Lopez, 1990). Given the extreme health and economic costs of smoking, improving interventions to help smokers quit is of paramount importance. Over two-thirds of smokers report that they want to quit smoking (CDC, 2011c). Better understanding the behavioral mechanisms that help smokers change their behavior will emphasize behavioral strategies to aid quitting smoking and address a major health concern.

The present study combined data from multiple intervention studies that effectively reduced smoking and utilized statistical mediation analysis to examine the mechanisms of smoking behavior change. Statistical mediation analysis is an advanced methodology that is ideal for investigating and quantifying mechanisms of behavior change. These tailored intervention studies were based on a widely-studied model of behavior change, the Transtheoretical Model (TTM).

Statistical Mediation Analysis

In general, mediation models are utilized to investigate how and why two things are related. Intermediate variables that come between independent variables and dependent variables are known as mediating variables, or mediators. A mediator acts as a third variable and represents the mechanism through which an independent variable influences an outcome (Baron & Kenny, 1986). The most basic model (MacKinnon, 2008) involves three key variables: an independent variable, X, a mediating variable, M, and a dependent variable, Y. From this simple model, additional independent variables, mediating variables, time points, and other components can be added to develop increasingly complex mediation models. In the framework of an intervention designed to change behavior, mediators are the mechanisms of behavior change. Thus, statistical mediation analysis was utilized in the present study to develop empirical models to better understand behavior change mechanisms.

A critical feature of the present series of mediation analyses is that all mediation models were longitudinal. Mediation models are also referred to as causal models, as mediators are hypothesized to cause changes in the dependent variables (and not the other way around) (Baron & Kenny, 1986). Thus, developing mediation models that demonstrate change over time requires longitudinal data to study the temporal order of change, as behavior change cannot be assumed to occur instantly. While mediation analyses can be performed with cross sectional data, the conclusions that can be drawn from such analyses are very limited (Gallob & Reichardt, 1991). Cross-sectional mediation analyses should be considered both inadequate and inappropriate to

study mechanisms of behavior change (Kazdin & Nock, 2003). Longitudinal mediation models require fewer assumptions, provide more accurate descriptions of the temporal order of change, and offer a more comprehensive evaluation of the mechanisms of change (MacKinnon, 2008).

The Transtheoretical Model of Behavior Change

The Transtheoretical Model is an integrative framework that consists of multiple dimensions that assess different components of behavior change (Prochaska & Velicer, 1997; Velicer, Prochaska, Fava, Rossi, Redding, Laforge, & Robbins, 2000). Essentially, the TTM represents a model of how individuals adopt healthy behaviors and discontinue unhealthy ones (Brewer & Rimer, 2008). The core constructs of the TTM include stages of change, processes of change, decisional balance, and self-efficacy. Tailored interventions based on the TTM have been empirically validated and have demonstrated effectiveness for a wide variety of behaviors, including smoking (Krebs, Prochaska, & Rossi, 2010; Noar, Benac, & Harris, 2007; Velicer, Prochaska, & Redding, 2006b; Velicer, Redding, Sun, & Prochaska, 2007b). The overall framework of the TTM is ideal for the development of mediation models because it can be conceptually summarized with three dimensions (Velicer et al., 2000): the temporal dimension (stages of change), the independent variable dimension (processes), and the intermediate variable dimension (decisional balance and self-efficacy).

Smoking research and the TTM have a very extensive history. Multiple components of the TTM were empirically refined with smoking as the content area, including stage of change (DiClemente et al., 1991), processes of change (Prochaska & DiClemente, 1983; Prochaska, Velicer, DiClemente, & Fava, 1988), decisional balance (Velicer, DiClemente, Prochaska & Brandenberg, 1985), and self-efficacy (Velicer, DiClemente, Rossi, & Prochaska, 1990), with longitudinal studies supporting predictive validity in some randomized and some nonrandomized studies (DiClemente et al., 1991; Prochaska, Velicer, Fava, Rossi, & Tsoh, 2001; Prochaska et al., 2004, 2005; Redding et al., 2011; Sun, Prochaska, Velicer, & LaForge, 2007; Velicer et al., 2006b, 2007b). The TTM has been applied to a wide variety of behaviors (e.g., alcohol use,

exercise, diet, UV protection, mammography screening), but it has been most widely applied to smoking (Krebs et al., 2010; Noar et al., 2007).

Mechanisms of Behavior Change and Interventions

Data from five TTM- tailored smoking interventions were utilized in the present study, and statistical mediation analysis was used to quantitatively deconstruct these intervention studies and determine which components, and which combinations of components, produced the treatment outcomes. Previous studies have explored potential mediators of smoking interventions with different statistical methods. Of particular relevance to the present study, some past research has investigated self-efficacy as a potential mediator of smoking cessation. Some studies have suggested that self-efficacy may function as a mediator of smoking cessation (Cinciripini et al., 2003; Vidrine, Arduino, & Gritz, 2006), while others have found mixed results (Gwaltney, Shiffman, Balabanis, & Paty, 2005; Unger et al., 2000). The present study investigated self-efficacy, as well as pros and cons, as mediators.

Overview of Current Study

Smokers that were identified as being in the preparation (PR) stage at the start of intervention were the focus of the present study. This is the third of a series of six studies that utilized statistical mediation analysis to better understand mechanisms of smoking behavior change in TTM-based studies. The first study focused on smokers in the precontemplation (PC) stage, and the second study focused on smokers in the contemplation (C) stage. Statistical mediation models were developed within separate stages, as opposed to combining individuals across stages, because differences in stage have consistently demonstrated nonlinear relations with the other TTM variables (Velicer, Prochaska, Rossi, DiClemente, 1996). The PR stage for smoking cessation includes smokers that report intending to quit in the next month and report having at least one successful 24-hour quit attempt in the past year. Individuals in the PR stage are highly motivated to quit smoking. Compared to the previous stages (PC and C), individuals in PR are more actively using the Processes of Change and are less tempted to smoke (DiClemente

et al., 1991; Fava et al., 1995; Velicer et al., 2000). In C, the Cons of Smoking begin to outweigh the Pros of Smoking; in PR, the Cons continue to outweigh the Pros (Hall & Rossi, 2008; Velicer et al., 1985). Among the pre-action stages (PC, C, and PR), preparation is associated with the highest rates of progression to action and maintenance (Blissmer et al., 2010). The proportion of smokers in the PR group, unfortunately, is consistently the smallest. In the United States, less than 20% of smokers are in the PR stage, while approximately 40% are in PC and 40% are in C (Velicer, Fava, Prochaska, Abrams, Emmons, & Pierce, 1995). Thus, most smokers are not as ready as those in PR to stop smoking.

The goal of the present study was to conduct a comprehensive series of statistical mediation analyses with data from TTM-based intervention studies to identify, for participants that were in the PR stage at baseline, which combinations of intervention components demonstrated empirical evidence of mediation. The analytical framework was guided by the TTM, with the ten processes of change acting as independent variables, pros, cons, and self-efficacy acting as mediators, and a smoking behavior outcome acting as the dependent variable. Each of the models only included one mediator, in order to isolate separate intervention components. All models were longitudinal, with data from assessments at three time points (baseline, 12 months, and 24 months). These variables produced a series of 30 single mediator models (10 processes * 3 mediators * 1 outcome) that were analyzed.

Method

Participants

Data from five different smoking intervention studies were combined in the present study. Combining data from multiple large studies was a necessary step to create a sample size large enough to analyze the complex statistical mediation models. This is particularly true for PR; individuals in PR consistently make up the smallest proportion of smokers in intervention studies (Velicer et al., 1995). These studies could be combined because of a number of crucial similarities. All five studies were large, randomized, clinical trials that were successful in

decreasing smoking rates. Each study collected longitudinal data, used representative, population-based sampling, and assessed all key TTM constructs (with the same items) necessary to run the mediation analyses. Only participants that received the same TTM-based smoking intervention were included in the combined sample; participants in control conditions or in other treatment groups were not included. Checking the validity of combining these studies by comparing within-study mediation models was included in a separate study (manuscript 6 in the present series of studies). The five separate studies that make up the combined sample were labeled Parent, Patient, Worksite, RDD, and Health. Sample sizes included below represent participants in PR at baseline.

Original Studies. The Parent study (Prochaska et al., 2004) involved parents of students recruited for a school-based study (N=50). In addition to a smoking intervention, participants in this study who were at risk also received interventions on diet and sun exposure. The Patient study (Prochaska et al., 2005) involved patients from an insurance provider list (N=136). In addition to a smoking intervention, participants in this study who were at risk also received interventions on diet, sun exposure, and mammography. The Worksite study (Velicer et al., 2004) involved employees from a sample of worksites (N=28). In addition to a smoking intervention, participants in this study who were at risk also received interventions on diet, sun exposure, and exercise. The RDD study (Prochaska et al., 2001) involved participants from a random digit dial (RDD) sample (N=228). This study intervened only on smoking. The Health study (Velicer, Friedman, Redding, Migneault, & Hoeppner, 2006a; Velicer, Friedman, Redding, Migneault, Hoeppner, & Prochaska, 2007a) involved participants who were smokers and who were at risk for diet and exercise in a multiple risk behavior study (N=57). In addition to a smoking intervention, participants in this study also received interventions on diet and exercise.

Total Combined Sample. The total combined sample for participants in PR at baseline was N = 499. Participants were 58.3% female and 89.8% white.

Intervention

All participants received a TTM-tailored smoking intervention that assessed key variables at baseline, 12 months, and 24 months. The smoking intervention was a tailored, expert system intervention, where participants received feedback matched to how they responded to TTM constructs. All interventions began with an assessment of basic demographic variables, smoking variables, and the core measures from the TTM. Interventions provided stage-matched and tailored feedback in a series of three reports at baseline, 3 months, and 6 months (RDD) or at baseline, 6 months, and 12 months (Parent, Patient, Worksite, and Health). Tailoring in these feedback reports involved both highlighting certain strategies to change (processes of change) as well as normative and ipsative comparisons. Data from studies with different intervention schedules were combined because these two different schedules did not produce different results (Velicer et al., 2007b). Participants in all interventions also received multiple follow-up assessments. Additional details involving the expert system intervention are available elsewhere (Velicer & Prochaska, 1999; Velicer et al., 1993).

Measures

Analyses performed in the present study involved all core TTM constructs, including stage of change, processes of change, decisional balance, and self-efficacy. Additional variables, related to smoking behavior, were also used to measure a latent variable for smoking outcome.

Stage of Change. The stages of change represent the temporal dimension of TTM and act as the central organizing framework of the model. Varying levels of readiness to change are represented by five stages: Precontemplation (PC), Contemplation (C), Preparation (PR), Action (A), and Maintenance (M) (DiClemente et al., 1991; Prochaska & DiClemente, 1983). Stages of change for smoking were assessed with algorithms developed to assess intentions to quit smoking (Prochaska & DiClemente, 1983). The PR stage includes participants that report being smokers, report intending to quit in the next month, and report having at least one successful 24-hour quit attempt in the past year.

Processes of Change. The processes of change represent the independent variable dimension of the TTM. The processes involve strategies for changing one's behavior; in TTM-based interventions, the processes play a critical role in tailoring the intervention to the individual. There are ten Processes of Change for Smoking (Prochaska et al., 1988). The ten processes include experiential processes, which are cognitive and emotional strategies to change behavior, and behavioral processes, which represent more overt changes in behavior. The experiential processes include Consciousness Raising, Dramatic Relief, Environmental Reevaluation, Self-Reevaluation, and Social Liberation. The behavioral processes include Counter Conditioning, Helping relationships, Reinforcement Management, Self Liberation, and Stimulus Control. Detailed descriptions of the Processes of Change for Smoking are available elsewhere (Prochaska et al., 1988). Participants were asked to rate how often they used each process in the last month on a 5-point Likert scale ranging from 1 (Never) to 5 (Repeatedly). Each of the processes was a latent variable measured by two items; details for the items are included in Appendix A. In the total sample, coefficient alphas for the Processes of Change for Smoking scales ranged from 0.60 to 0.84.

Decisional Balance. The decisional balance construct represents part of the intermediate variable dimension of the TTM. Decisional balance, originally adapted from Janis and Mann (1977), assess an individual's weighing of the pros and cons of engaging in a behavior. The relationship between decisional balance and the stages of change has been replicated across more than 48 different health behaviors (Hall & Rossi, 2008). The Decisional Balance Scale for Smoking is a six-item scale with three items for the Pros of Smoking and three items for the Cons of Smoking (Velicer et al., 1985). These items assess the relative importance of the pros and cons of smoking. Participants were asked to rate the importance of each item on a 5-point Likert scale ranging from 1 (Not important) to 5 (Extremely important). The Pros of Smoking and the Cons of Smoking were represented by latent variables, each measured by three items; details for the items

are included in Appendix A. In the total sample, coefficient alpha was 0.70 for the Pros of Smoking and 0.66 for the Cons of Smoking.

Self-Efficacy. The self-efficacy construct represents the other part of the intermediate variable dimension of the TTM. Originally adapted from Bandura (1977), the self-efficacy construct assesses an individual's perceived ability to perform behaviors in difficult situations. Self-efficacy increases as one transitions TTM stages (Velicer et al., 1990). Improved self-efficacy predicts improved outcomes; this relationship has been repeatedly demonstrated for smoking (Blissmer et al., 2010; Prochaska, DiClemente, Velicer, Ginpil, & Norcross, 1985; Prochaska, Velicer, DiClemente, Guadagnoli, & Rossi, 1991). In the framework of the TTM, self-efficacy either describes the confidence to engage in a healthy behavior or describes temptations to engage in an unhealthy behavior. For smoking, self-efficacy is measured by the Situational Temptations to Smoke scale (Velicer et al., 1990). The Situational Temptations describe situations that may lead some people to smoke. The instrument is a nine-item scale with three items for positive affect / social situations, three items for negative affect situations, and three items for habitual / craving situations. Participants were asked to rate how tempted to smoke they felt on a 5-point Likert scale ranging from 1 (Not at all tempted) to 5 (Extremely tempted). Details for the items are included in Appendix A. In the present study, averages of these three item content areas (e.g., positive affect / social situations) were calculated to represent Situational Temptations for Smoking with three items; a latent variable for Situational Temptations was measured by these three items. Coefficient alpha for this three-item scale was 0.78 in the total sample.

Smoking Outcome. The smoking behavioral outcome was a latent variable measured by two key items from the widely-used Fagerstrom Test for Nicotine Dependence (FTND; Fagerstrom, 1978), time to first cigarette and number of cigarettes smoked per day. These two continuous variables were converted to 5-point scales, with higher values indicating more

smoking. Details for the items are included in Appendix A. Coefficient alpha for this measure was 0.75 in the total sample.

Statistical Analysis

Development of the series of 30 single mediator models can be summarized by two phases of analysis. The first phase involved the creation of models that best fit the data. The second phase involved the assessment of paths within the models to search for evidence of statistical mediation.

Creation and Fit Assessment of Mediation Models. Developing models that fit the data is essential to establishing a framework for statistical mediation. Creation of the single-mediator models was guided by the hypothesized TTM framework, where processes are the independent variables (X), decisional balance (pros, cons) and self-efficacy are mediators (M), and the smoking outcome is the dependent variable (Y). In the present study, only participants that were PR at baseline were included. This set of variables (10 processes * 3 mediators * 1 outcome) produced a total of 30 single-mediator models.

All of the mediation models in the present study were latent variable models. The use of latent variables improves the reliability of the measures (MacKinnon, 2008). Data were available at baseline, 12 months, and 24 months, and therefore all mediation models were longitudinal, three-wave models. These models represent autoregressive mediation models (Cole & Maxwell, 2003; Gallob & Reichardt, 1991, MacKinnon, 2008). In longitudinal, autoregressive, three-wave mediation models, each variable is predicted by the same variable at an earlier wave. Due to the number of parameters being estimated in each model, and the use of latent variables, structural equation modeling (SEM) was an ideal analytic tool to assess these mediation models (Iacobucci, Saldanha, & Deng, 2007; MacKinnon, 2008).

SEM was utilized to analyze the covariance structure, estimate regression paths, estimate error terms, and assess model fit. Missing data, which are extremely common in longitudinal studies, were estimated with maximum likelihood (ML) procedures. Using ML methods in SEM

has been demonstrated to be accurate and less biased than conventional methods such as listwise or pairwise deletion (Allison, 2003; Enders & Bandalos, 2001). The following commonly-used indices were used as benchmarks to assess the model fit: likelihood ratio chi-square ($\chi 2$), Normed Fit Index (NFI), Comparative Fit Index (CFI), and Root Mean Squared Error of Approximation (RMSEA). Likelihood ratio chi-square provides a test for fit of the model based on the chi-squared distribution. The chi-square test is extremely sensitive to large sample sizes (Kline, 2005) and will always reject models with large sample sizes. Due to this issue, and the large sample sizes in the present study, chi-square values are reported but results for its associated significance test are not. For NFI and CFI, values greater than 0.90 indicate good fit and values greater than 0.95 indicate very good fit (Bentler & Bonnet, 1980; Kline, 2005). For RMSEA, values less than 0.10 indicate good fit and values less than 0.05 indicate very good fit (Browne & Cudeck, 1993). An important goal of creating longitudinal mediation models in SEM was to find a model that fit well across all 30 single mediator combinations. A common underlying model created the opportunity to compare results across the 30 single mediator models.

Assessing Statistical Mediation. Evaluating the regression paths was necessary to determining which combinations of variables actually demonstrated empirical evidence of statistical mediation. Analysis with SEM includes the estimation of regression paths among the variables. In three-wave autoregressive mediation models, two paths are particularly important to mediation: X at time 1 to M at time 2 (path a_1) and M at time 2 to Y at time 3 (path b_2). Together, these two paths represent the mediation pathway, which is also known as the indirect effect or the intervening effect (MacKinnon, Lockwood, & Williams, 2004; Preacher & Hayes, 2008; Sobel, 1982). Statistical significance of each of these paths was assessed separately in SEM; if each path demonstrated statistical significance, this finding suggests that the mediation pathway may be significant. To further assess for evidence of mediation, asymmetric confidence intervals for the product of these paths were calculated (MacKinnon, 2008; Tofighi & MacKinnon, 2011). If the confidence interval did not include zero, there was evidence of statistical mediation.

There is no consensus on what estimates best represent effect sizes for statistical mediation analysis, and this topic represents an area that is currently under refinement (Fairchild, MacKinnon, Taborga, & Taylor, 2009; Preacher & Kelly, 2011; MacKinnon, 2008). In the present study, standardized coefficients for a_1 and b_1 were reported, as well as the product of the standardized coefficients (MacKinnon, 2008). These estimates help describe the magnitude of the mediated effect and will be interpreted similarly to R^2, where product absolute values of 0.01, 0.06, and 0.13 correspond to small, medium, and large effect sizes (Cohen, 1992).

Results

Creation and Fit Assessment of Mediation Models

As a first step, descriptive analyses were performed on the combined dataset (N = 499) to check for extreme skewness and kurtosis values for the study variables (West, Finch, & Curran, 1995). All skewness variables and kurtosis values were between -2 and 2. Basic descriptive statistics for the averages of study variables (means and standard deviations) are included in Table 3.1.

SEM was employed with EQS 6.1 software (Bentler, 2007) to develop the single mediator models. Suggestions from Cole and Maxwell (2003) and MacKinnon (2008) were utilized to create a variety of autoregressive mediation models, including a basic autoregressive mediation model (autoregressive mediation model I), a more advanced model (autoregressive mediation model II), and a fully cross-lagged model. Fit statistics across these sample models consistently suggested that an autoregressive model II best fit the data. The template for the autoregressive mediation model II is included in Figure 3.1. There are six key characteristics to the autoregressive mediation model II (MacKinnon, 2008). First, relations are modeled one lag apart (e.g., 12 months to 24 months). Second, relations between the same variables over time are modeled to assess stability (the *s* coefficients). Third, the model includes regression paths that describe longitudinal mediation (e.g., independent variable at time 1 to mediator at time 2, independent variable at time 1 to dependent variable at time 2). Fourth, covariances among the

variables at the first wave are estimated. Fifth, covariances among error terms are estimated at each wave. Sixth, relations between the independent variable and mediator, as well as mediator and dependent variable, are modeled. This is called contemporaneous mediation; the purpose of these paths is to help account for change that occurs between the time points. With the autoregressive model II framework selected, all 30 single mediator models were created.

Model Fit Statistics. The series of 30 mediation models (10 processes * 3 mediators * 1 outcome) were successfully created. First, the models were conducted using complete cases only. Fit statistics from the complete case analysis are included in Table 3.2. With the Pros of Smoking as mediators, six out of ten models demonstrated a very good fit (CFI > 0.95, RMSEA < 0.05), and the remaining four demonstrated a good fit (CFI > 0.90, RMSEA < 0.10). With the Cons of Smoking as mediators, five out of ten models demonstrated a very good fit (CFI > 0.95, RMSEA < 0.05), and the remaining five demonstrated a good fit (CFI > 0.90, RMSEA < 0.10). With Situational Temptations as mediators, three out of ten models demonstrated a very good fit (CFI > 0.95, RMSEA < 0.05), and the remaining seven demonstrated a good fit (CFI > 0.90, RMSEA < 0.10). Overall, all 30 mediation models demonstrated a good fit or better.

Second, due to the large number of participants that had missing data on one or more of the variables (over 50% of the sample), the models were conducted using ML to estimate missing data. Fit statistics from the ML models are included in Table 3.3. The conclusions from these fit statistics matched the complete case analysis, with all models demonstrating exceptional fit.

Assessing Statistical Mediation

To assess the models for evidence of statistical mediation, the longitudinal regression paths estimated in SEM were evaluated. The mediation pathway (process at baseline to mediator at 12-months, a_1, and mediator at 12-months to outcome at 24-months, b_2) within each model was assessed in two steps. First, the statistical significance of each path (a_1 and b_2 in Figure 3.1) was assessed. Second, the RMediation (Tofighi & MacKinnon, 2011) application was employed to estimate asymmetric confidence intervals for the product of these paths. Models estimated with

complete case analysis and models estimated with ML for missing data were assessed for evidence of statistical mediation. In all cases, the conclusions from both sets of models were equivalent. Results from models that included missing data estimation with ML are reported, as these estimates are less biased (Allison, 2003; Enders & Bandalos, 2001).

Statistical Mediation with Pros of Smoking as Mediator. Unstandardized and standardized longitudinal regression paths describing the mediation pathway through the Pros of Smoking are included in Table 3.4. Of the ten Processes of Change for Smoking, none of the processes demonstrated evidence of statistical mediation through the Pros of Smoking.

Statistical Mediation with Cons of Smoking as Mediator. Unstandardized and standardized longitudinal regression paths describing the mediation pathway through the Cons of Smoking are included in Table 3.4. Of the ten Processes of Change for Smoking, none of the processes demonstrated evidence of statistical mediation through the Cons of Smoking.

Statistical Mediation with Situational Temptations as Mediator. Unstandardized and standardized longitudinal regression paths describing the mediation pathway through the Situational Temptations to Smoke are included in Table 3.4. Of the ten Processes of Change for Smoking, one of the processes demonstrated statistical significance for both components of the mediation pathway. This process, with standardized regression paths, was Self-Reevaluation (std. a_1 = -0.267, std. b_2 = -0.497). The product, asymmetric confidence interval, and product of standardized coefficients are included in Table 3.5. Self-Reevaluation had a confidence interval that did not include zero (0.039, 0.916; std. product = 0.133, large effect). A diagram is included in Figure 3.2.

Discussion

Advanced statistical mediation analysis techniques were utilized to investigate variables hypothesized to underlie changes in smoking behavior. A series of 30 single mediator models for participants in the PR stage for smoking at baseline was successfully conducted. Smokers in the PR stage report intentions to quit smoking in the next month and report having at least one

successful 24-hour quit attempt in the past year. All models utilized the framework of an autoregressive mediation model II (MacKinnon, 2008), had three time points (baseline, 12 months, and 24 months), and employed SEM to estimate covariance structure, regression paths, error terms, missing data with ML, and assess model fit. All models demonstrated a great fit, but evidence for statistical mediation was only found through one combination, Self-Reevaluation through Situational Temptations.

Models with the Pros and Cons of Smoking as Mediators

The Pros of Smoking and the Cons of Smoking were hypothesized as potential mediating variables because of consistent evidence that the Pros decrease and the Cons increase as smokers make progress to quitting smoking (Hall & Rossi, 2008). Unfortunately, for participants starting intervention in the PR stage, zero of the ten Processes of Change for Smoking were found to demonstrate evidence of statistical mediation through the Pros of Smoking and the Cons of Smoking. These null findings across 20 separate models were unexpected, particularly considering how multiple Processes of Change for Smoking were found to demonstrate evidence of statistical mediation through both the Pros of Smoking and the Cons of Smoking in separate studies that evaluated participants in PC and C at baseline (manuscript 1 and manuscript 2 in the present series of studies).

Models with Situational Temptations as Mediator

Situational Temptations to Smoke represent situations where smokers would feel tempted to smoke (Velicer et al., 1990). Situational Temptations were hypothesized as a potential mediator because of evidence that temptations typically decrease as a smoker makes progress to quitting smoking (Blissmer et al., 2010; Prochaska et al., 1985; Prochaska et al., 1991). For participants starting intervention in the PR stage, one of the Processes of Change for Smoking was found to demonstrate evidence of statistical mediation through the Situational Temptations to Smoke. Evidence from significance tests of regression paths and asymmetric confidence intervals

suggested that Self-Reevaluation influenced the temptations, which in turn influenced the smoking outcome.

The Processes of Change for Smoking have a correlated higher-order factor structure with two dimensions: experiential processes and behavioral processes (Prochaska et al., 1988). The experiential processes involve cognitive and emotional strategies to change behavior, and are typically most important to smokers in the pre-action stages (Prochaska, DiClemente, & Norcross, 1992). Self-Reevaluation is one of the experiential processes of change, and this finding provides evidence of the validity of this prediction from TTM.

In all mediation models for participants in PR at baseline with Situational Temptations as a mediator, both the unstandardized path coefficients from Situational Temptations at 12 months to smoking outcome at 24 months (b_2) and their associated standard errors were very large compared to all other paths that were assessed (see Table 3.4). This pattern was not found in mediation models developed for participants in PC or C at baseline (manuscript 1 and manuscript 2 in the present series of studies). These exceptionally strong and variable paths were likely the result of the high correlations among Situational Temptations and smoking in the PR stage. With the Pros of Smoking consistently outweighing the Cons of Smoking, Situational Temptations become an increasingly strong predictor of smoking; in some cases, Situational Temptations have been proposed as a smoking outcome variable (Velicer et al., 1996). This finding highlights the importance of considering both parts of the mediation path, as all ten b_2 paths demonstrated statistical significance. The path from the Processes of Change for Smoking at baseline to Situational Temptations at 12 months (a_1) was only significant for Self-Reevaluation.

Overall Patterns

All five separate studies that were combined to create the sample for the present study were successful in decreasing smoking rates. By breaking apart the intervention components and investigating statistical mediation over time, these studies have essentially undergone a quantitative dissection to reveal what intervention components drove the outcomes. The Pros of

Smoking and the Cons of Smoking did not demonstrate evidence of statistical mediation with any of the Processes of Change for Smoking. Self-Reevaluation was found to demonstrate evidence of statistical mediation through Situational Temptations, with a large effect (product of standardized paths = 0.133). This finding suggests that intervening on Self-Reevaluation played an important role in driving the smoking outcomes. Self-Reevaluation involves individuals feeling upset or disappointed in themselves for their smoking. Such negative feelings seem to be important to influencing temptations for participants beginning intervention in the PR stage.

The lack of evidence of statistical mediation through the pros and cons is an important finding to consider. While the sample size for the PR group was less than half of the sample sizes available for PC and C, an inadequate sample size does not account for the null findings. The complete case analyses for PC and C had sample sizes very similar to the size of the PR group with missing data estimated with ML, and these analyses produced robust evidence of statistical mediation (manuscript 1 and manuscript 2 in the present series of studies).

Instead, the characteristics of the PR stage help explain why none of the Processes of Change for Smoking were found to mediate smoking behavior through the Pros of Smoking and the Cons of Smoking. The preparation stage is a particularly heterogeneous group. Empirical evidence for the importance of the PR stage was first published in 1991 (DiClemente et al., 1991); while this stage was included in earlier formulations of the TTM, it was not included in earlier publications. Instead, the C stage included individuals that would now be considered in the PR stage (DiClemente et al., 1991; Prochaska & DiClemente, 1983). Individuals in PR are very ready to quit smoking, as evidenced by the fact that they had at least one successful 24-hour quit attempt in the past year. Compared to the other pre-action stages, those in PR are using the Processes of Change for Smoking the most (DiClemente et al., 1991; Fava et al., 1995). Since they are already utilizing the Processes at baseline, the lack of evidence of statistical mediation may be due to a comparatively small change in process use over time. Additionally, while the Pros and Cons change dramatically from PC to C, the change in decisional balance is less

dramatic from PR to action (Hall & Rossi, 2008). Thus, for those starting an intervention in PR, the lack of evidence for statistical mediation for the Processes of Change of Smoking through the Pros and Cons may be partially due to the comparatively small amount of change in these constructs over time.

The two paths that made up the mediation pathway, process at baseline to mediator at 12 months (a_1) and mediator at 12 months to smoking outcome at 24 months (b_2), were the focus of the present study, but there were many other paths that revealed important information about statistical mediation. Two additional paths that were important to mediation were the two direct effects, process at baseline to smoking outcome at 12 months (c'_1) and process at 12 months to smoking outcome at 24 months (c'_2). These paths describe the relations from the independent variables to the dependent variables, adjusted for the effects of the mediators. In statistical mediation models, effective mediators should result in comparatively small direct effects, and in the present study, the direct effects were consistently very small. The path from mediator at baseline to smoking outcome at 12 months (b_1) also described important patterns. In general, the magnitude of the b_1 path was smaller than the magnitude of the b_2 path. This pattern provides evidence of an intervention effect; the relation between the mediator and the outcome consistently increased over time. Examples of these relations are included in Figure 3.2.

Limitations

The use of secondary data represents the biggest limitation to the present study. Limitations from the original studies impacted the statistical mediation analyses in a number of ways. First, the diversity of the sample was suboptimal; each of the five studies was primarily white, and the combined sample was nearly 90% white. A substantially more diverse sample, with more participants of different races and different ethnicities, would greatly improve the validity of these statistical mediation models. Additionally, a truly international sample would further increase the generalizability of the results, and the results would better represent the true underlying mechanisms of smoking behavior change.

Second, the details of the tailored interventions produced some limitations. The five original studies that comprised the combined sample all utilized stage-matched tailoring; participants in different stages received feedback that emphasized certain processes of change. For example, participants in PC typically received feedback that highlighted experiential processes of change, such as Consciousness Raising, Environmental Reevaluation, and Self-Reevaluation. Since participants did not receive an equal amount of feedback for each of the ten processes, the tailoring may have impacted process use differentially. Determining the extent to which the tailoring influenced the relations among the processes and the mediators was impossible because control groups could not be included in the analyses. All analyses were conducted on participants that were in treatment groups, and the lack of control groups created multiple important limitations. Analyses could not be performed because the processes of change were not assessed in the control conditions of the original studies (to reduce contamination due to measurement). Comparisons among the treatment and control groups would have revealed important intervention effects as well as additional insight into the mechanisms of smoking behavior change. If the mediation relations described in the present study truly represent mechanisms of behavior change for smoking, control groups would demonstrate similar relations, but with lower magnitudes, as TTM interventions are thought to accelerate naturalistic processes of behavior change (Prochaska & Velicer, 1997; Velicer et al., 2000; Velicer et al., 2006b). Additionally, evidence for causality was limited due to the lack of data from control groups; comparing data from randomized treatment and control conditions would greatly enhance evidence of causal relations.

Third, measurement issues from the original studies resulted in some limitations. The lack of data for the processes of change in control groups, as discussed above, was the biggest limitation. Another limitation was that the short forms of all measures were utilized. For example, each of the processes of change was measured by two items. In the intervention studies, this was necessary to prevent the assessments from being unreasonably long. For the present study,

measures with more items would have been very beneficial. Coefficient alpha values for many measures, including the processes of change, pros, and cons were often low (but still within an acceptable range); internal consistency for each measure would be improved with additional items. Additional items for measures may have also improved the predictive power of constructs. Relations among processes of change and mediators, as well as processes of change and smoking outcomes, were typically smaller in magnitude than the relations among mediators and smoking outcomes. This finding may be partially explained by the two-item scales for the processes. Additional items for each of the processes could increase the magnitude of relations, and this could result in more evidence for statistical mediation.

Smoking outcome was an important component of all mediation models and was associated with some limitations. Unlike other constructs in the present study (e.g., Consciousness Raising, Cons of Smoking), which were previously validated in past studies, the smoking outcome was specifically developed to perform statistical mediation models for smoking. The two items that measured the latent variable for smoking outcome, time to first cigarette and cigarettes per day, have been used extremely often in smoking intervention studies, but are typically not combined as a latent variable. Thus, the measure could benefit from more vigorous psychometric testing in the future. As with the other scales, the smoking outcome would be strengthened by additional items. One type of item that would be particularly beneficial for the smoking outcome would be an item that reflected stage progression. Regardless, the smoking outcome variable in the present study (as well as separate studies that evaluated mediation with PC and C) performed very well, and correlated highly with Situational Temptations to Smoke, which has been used in the past as a smoking outcome variable (Velicer et al., 1996).

Fourth, timing issues related to both measurement and intervention were also limitations. At least three time points were necessary to run the longitudinal mediation models; baseline, 12 months, and 24 months were selected because all original five studies had full assessments at these time points. However, in all of these studies the intervention was complete by the 12-month

time point. Thus, the most dramatic changes may have occurred between baseline and 12 months, but these could not be fully captured in the mediation models. The changes from 12 months to 24 months involved the lasting effects of the intervention. The mediation models in the present study described changes over a wide time frame, and they would be improved with additional time points.

All of these areas of limitations could be addressed with a study specifically designed to test mediational hypotheses. An ideal TTM-tailored intervention study to test mediation would (1) recruit a large, diverse sample; (2) collect data for all TTM constructs for both treatment and control groups; (3) utilize scales for TTM constructs that had more than two items each and include extra items to assess smoking behavior; and (4) perform full assessments (at least) every six months. With the data produced by such a study, the resulting mediation models would provide very compelling evidence of the mechanisms of smoking behavior change.

An important limitation of the present study, likely unrelated to the use of secondary data, involved the signs of the regression paths in the mediation models. In many instances, the signs of regression paths were opposite from what was expected. The longitudinal regression paths in particular had some unusual patterns. Notably, the path from the mediator at 12 months to the smoking outcome at 24 months (b_2) in the mediation pathway was consistently found to be negative. This negative path is challenging to interpret. For example, consider Situational Temptations; a negative b_2 coefficient would suggest that a decrease in temptations at 12 months predicts an increase in smoking at 24 months, which is incorrect. In fact, the Situational Temptations at 12 months were positively, not negatively, correlated with the smoking outcome at 24 months. Paths with unexpectedly negative signs were also found in the evaluation of statistical mediation models at PC and C (manuscript 1 and manuscript 2 in the present series of studies). This unexpected finding suggests the presence of suppressor effects (Kline, 2005; MacKinnon, 2008; Velicer, 1978). Suppressor effects are common in longitudinal structural

equation models and are even more common when latent variables are involved (Maassen & Bakker, 2001).

The unexpectedly negative b_2 paths likely represent examples of negative suppression, where the signs are reversed due to the presence of other, stronger positive predictors of smoking outcome at 24 months. For the b_2 path from Situational Temptations at 12 months to smoking at 24 months, these other predictors included smoking outcome at 12 months and Situational Temptations at 24 months. Further evidence of suppression was found through modification of the models. When one of the strong predictors of smoking outcome at 24 months was deleted from the model (either the smoking outcome at 12 months or Situational Temptations at 24 months), the sign of the longitudinal mediation path b_2 flipped from negative to positive. This suggested that b_2 was negative simply because of the other predictors. Due to suppression effects, the signs of regression paths need to be interpreted with caution. Instead, effect sizes should be the emphasis of interpretation. The magnitude of each regression path, as described by the standardized coefficients, is very important. The effect size of the overall mediation pathway, calculated from the product of the standardized coefficients, is also more important to describing mediation than the signs of any individual paths.

In addition to the b_2 paths being distorted by suppressor effects, the a_1 paths need to be interpreted with caution for some of the Processes of Change. Some processes were found to have a positive coefficient from process use at baseline to the Pros of Smoking and Situational Temptations at 12 months. This suggests that increasing the use of these Processes of Change predicts higher Pros of Smoking and higher temptations at 12 months, which is an opposite pattern from the other processes. These unexpected results may be the result of suppressor effects. This may be particularly true for the models with Situational Temptations as a mediator, as the relations among temptations and smoking were found to be particularly strong. These patterns may also represent relations that were simply not anticipated. For example, increased use of the processes may be associated with increased Situational Temptations 12 months later because such

processes represent strategies to cope with strong temptations, and temptations do not decrease until late stages (Blissmer et al., 2010; Prochaska et al., 1985; Prochaska et al., 1991; Velicer et al., 1996). Future studies looking at relapse, with smokers in the action or maintenance stage for smoking, could help explain this finding.

Future Directions for Analysis

An important validity check for the statistical mediation models developed in the present study will be whether the estimates are consistent across subsamples. For example, different age groups may demonstrate different patterns within the model with Self-Reevaluation and Situational Temptations. In the framework of SEM, multiple subsamples can be compared simultaneously with factorial invariance procedures (Meredith, 1993). A separate study (manuscript 6 in the present series of studies) will evaluate factorial invariance across a series of subgroup variables, including age, education level, gender, race, and study.

Conclusions

For those beginning intervention in PR, Situational Temptations was found to be an important mediator, and Self-Reevaluation was found to be the most important of the Processes of Change for Smoking. Better understanding which behavioral variables are the most important and most relevant for individuals will directly contribute to future interventions; new interventions can be tailored to focus on the variables that are most likely to have the biggest effects on behavioral outcomes. Modern, computerized interventions will be able to adapt to make intervention contacts as relevant as possible by tailoring to individuals to focus on which behavioral mechanisms are the most important to changing behavior. Future improvement and refinement of statistical mediation models will directly lead to improvement and refinement of smoking cessation interventions, and development of more effective interventions for smoking will address a major concern for public health.

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Table 3.1. Average means with standard deviations for participants at PR at baseline for independent variables (ten Processes of Change for Smoking Cessation), mediators (Pros, Cons, Situational Temptations), and dependent variables (smoking outcome) at the baseline, 12-month, and 24-month time points

Variable	Baseline		12 Months		24 Months	
	Mean	SD	Mean	SD	Mean	SD
Independent Variables						
Experiential processes						
Consciousness Raising	3.409	1.008	3.191	1.038	3.037	1.172
Dramatic Relief	3.080	1.169	2.949	1.193	2.944	1.274
Environmental Reevaluation	3.105	1.313	2.838	1.271	2.840	1.338
Self-Reevaluation	3.683	1.119	3.466	1.202	3.331	1.332
Social Liberation	3.979	0.974	3.910	0.992	3.942	1.084
Behavioral Processes						
Counter Conditioning	2.629	0.914	2.879	1.077	2.830	1.133
Helping Relationships	2.719	1.358	2.727	1.299	2.748	1.402
Reinforcement Management	2.278	1.282	2.284	1.240	2.316	1.449
Self Liberation	3.733	1.038	3.711	1.073	3.562	1.214
Stimulus Control	1.983	1.051	2.219	1.158	2.203	1.233
Mediators						
Pros	2.456	0.902	2.354	0.978	2.175	1.000
Cons	3.419	1.027	3.328	1.135	3.217	1.283
Situational Temptations	3.224	0.715	3.024	0.956	2.781	1.077
Dependent Variables						
Smoking Outcome	2.988	0.834	2.668	1.142	2.488	1.238

All variables on a 1-5 scale; see appendix for additional materials on the scales

Table 3.2. Fit indices at PR for all mediation models, complete case analysis

Model	N	χ^2	(df)	NFI	CFI	RMSEA	(90% RMSEA)
Mediator: Pros of Smoking							
Consciousness Raising	182	186.773	(149)	0.873	0.970	0.037	(0.016, 0.053)
Dramatic Relief	182	198.063	(149)	0.885	0.968	0.043	(0.025, 0.057)
Environmental Reevaluation	182	182.591	(149)	0.906	0.981	0.035	(0.010, 0.051)
Self-Reevaluation	182	222.274	(149)	0.881	0.957	0.051	(0.036, 0.065)
Social Liberation	181	207.661	(149)	0.866	0.958	0.046	(0.029, 0.060)
Counter Conditioning	182	265.895	(149)	0.839	0.920	0.065	(0.052, 0.077)
Helping Relationships	182	283.996	(149)	0.862	0.928	0.070	(0.057, 0.082)
Reinforcement Management	182	303.891	(149)	0.857	0.920	0.075	(0.062, 0.087)
Self Liberation	182	206.282	(149)	0.870	0.959	0.046	(0.029, 0.060)
Stimulus Control	182	180.773	(149)	0.887	0.977	0.034	(0.008, 0.051)
Mediator: Cons of Smoking							
Consciousness Raising	182	164.352	(149)	0.891	0.989	0.023	(0.000, 0.043)
Dramatic Relief	182	235.493	(149)	0.869	0.947	0.056	(0.041, 0.069)
Environmental Reevaluation	182	234.451	(149)	0.884	0.954	0.055	(0.041, 0.068)
Self-Reevaluation	182	182.448	(149)	0.895	0.978	0.035	(0.011, 0.051)
Social Liberation	181	241.024	(149)	0.847	0.934	0.058	(0.043, 0.071)
Counter Conditioning	182	213.630	(149)	0.863	0.953	0.048	(0.033, 0.062)
Helping Relationships	182	222.706	(149)	0.887	0.960	0.051	(0.035, 0.064)
Reinforcement Management	182	165.396	(149)	0.915	0.992	0.023	(0.000, 0.043)
Self Liberation	182	173.660	(149)	0.889	0.983	0.030	(0.000, 0.047)
Stimulus Control	182	221.184	(149)	0.866	0.951	0.051	(0.035, 0.064)
Mediator: Situational Temptations							
Consciousness Raising	183	195.278	(149)	0.911	0.977	0.041	(0.023, 0.056)
Dramatic Relief	183	212.133	(149)	0.914	0.972	0.048	(0.032, 0.062)
Environmental Reevaluation	183	219.459	(149)	0.919	0.972	0.051	(0.036, 0.065)
Self-Reevaluation	183	200.306	(149)	0.919	0.978	0.042	(0.024, 0.057)
Social Liberation	182	215.384	(149)	0.905	0.968	0.050	(0.034, 0.063)
Counter Conditioning	183	256.563	(149)	0.890	0.949	0.063	(0.050, 0.076)
Helping Relationships	183	304.859	(149)	0.891	0.940	0.075	(0.062, 0.087)
Reinforcement Management	183	341.434	(149)	0.881	0.929	0.083	(0.071, 0.095)
Self Liberation	183	220.155	(149)	0.905	0.967	0.051	(0.035, 0.064)
Stimulus Control	183	217.911	(149)	0.907	0.968	0.050	(0.035, 0.064)

Table 3.3. Fit indices at PR for all mediation models, missing data estimated with ML

Model	N	χ^2	(df)	NFI	CFI	RMSEA	(90% RMSEA)
Mediator: Pros of Smoking							
Consciousness Raising	499	201.569	(149)	1.000	1.000	0.000	-
Dramatic Relief	499	192.918	(149)	1.000	1.000	0.000	-
Environmental Reevaluation	499	182.447	(149)	1.000	1.000	0.000	-
Self-Reevaluation	499	218.046	(149)	0.998	1.000	0.000	-
Social Liberation	499	203.798	(149)	1.000	1.000	0.000	-
Counter Conditioning	499	292.388	(149)	1.000	1.000	0.000	-
Helping Relationships	499	181.206	(149)	1.000	1.000	0.000	-
Reinforcement Management	499	312.422	(149)	0.961	1.000	0.000	-
Self Liberation	499	242.362	(149)	0.982	1.000	0.000	-
Stimulus Control	499	215.751	(149)	1.000	1.000	0.000	-
Mediator: Cons of Smoking							
Consciousness Raising	499	266.212	(149)	0.941	1.000	0.000	(0.000, 0.019)
Dramatic Relief	499	259.579	(149)	0.950	1.000	0.000	(0.000, 0.019)
Environmental Reevaluation	499	197.453	(149)	0.995	1.000	0.000	-
Self-Reevaluation	499	272.882	(149)	0.951	1.000	0.000	(0.000, 0.019)
Social Liberation	499	261.347	(149)	0.946	1.000	0.000	(0.000, 0.014)
Counter Conditioning	499	223.289	(149)	1.000	1.000	0.000	-
Helping Relationships	499	245.896	(149)	0.959	1.000	0.000	(0.000, 0.007)
Reinforcement Management	499	173.804	(149)	1.000	1.000	0.000	-
Self Liberation	499	271.026	(149)	0.953	1.000	0.000	-
Stimulus Control	499	189.591	(149)	1.000	1.000	0.000	-
Mediator: Situational Temptations							
Consciousness Raising	499	210.145	(149)	0.992	1.000	0.000	-
Dramatic Relief	499	238.976	(149)	0.996	1.000	0.000	-
Environmental Reevaluation	499	244.373	(149)	0.997	1.000	0.000	-
Self-Reevaluation	499	262.478	(149)	0.981	1.000	0.000	-
Social Liberation	499	244.261	(149)	1.000	1.000	0.000	-
Counter Conditioning	499	319.342	(149)	0.989	1.000	0.000	-
Helping Relationships	499	341.611	(149)	0.963	0.998	0.012	(0.000, 0.024)
Reinforcement Management	499	253.037	(149)	1.000	1.000	0.000	-
Self Liberation	499	245.491	(149)	0.999	1.000	0.000	-
Stimulus Control	499	268.744	(149)	1.000	1.000	0.000	-

- Lower confidence limit negative, interval not calculated

Table 3.4. Unstandardized (with standard errors) and standardized longitudinal regression paths describing the mediation pathway; Processes of Change at baseline to mediator at 12 months (a_1) and mediator at 12 months to smoking outcome at 24 months (b_2)

Model	a_1	s.e.	Std. a_1	b_2	s.e.	Std. b_2
Mediator: Pros of Smoking						
Consciousness Raising	-0.474	0.365	-0.351	-0.052	0.147	-0.037
Dramatic Relief	-0.288	0.181	-0.212	-0.066	0.154	-0.047
Environmental Reevaluation	-0.129	0.126	-0.098	-0.068	0.161	-0.047
Self-Reevaluation	-0.398*	0.189	-0.281	-0.082	0.140	-0.061
Social Liberation	-0.176	0.247	-0.132	-0.069	0.149	-0.048
Counter Conditioning	0.691	0.419	0.419	-0.018	0.126	-0.016
Helping Relationships	-0.138	0.117	-0.104	-0.066	0.156	-0.046
Reinforcement Management	-0.102	0.113	-0.077	-0.110	0.164	-0.075
Self Liberation	-0.006	0.112	-0.005	-0.045	0.157	-0.031
Stimulus Control	0.259	0.147	0.189	-0.007	0.154	-0.005
Mediator: Cons of Smoking						
Consciousness Raising	-1.047	0.878	-0.451	-0.031	0.157	-0.038
Dramatic Relief	-0.623*	0.302	-0.373	0.011	0.123	0.010
Environmental Reevaluation	-0.309	0.167	-0.196	-0.013	0.107	-0.012
Self-Reevaluation	-0.634	0.365	-0.302	-0.090	0.132	-0.097
Social Liberation	-0.525	0.372	-0.280	-0.064	0.128	-0.060
Counter Conditioning	-0.870	0.641	-0.584	-0.041	0.180	-0.037
Helping Relationships	-0.349*	0.138	-0.226	-0.010	0.128	-0.008
Reinforcement Management	-0.210	0.153	-0.140	-0.013	0.100	-0.011
Self Liberation	-0.393*	0.180	-0.227	0.195	0.140	0.177
Stimulus Control	-0.737*	0.322	-0.416	-0.039	0.107	-0.041
Mediator: Situational Temptations						
Consciousness Raising	-0.265	0.204	-0.208	-1.207*	0.472	-0.526
Dramatic Relief	-0.248	0.144	-0.198	-1.295*	0.508	-0.544
Environmental Reevaluation	0.001	0.099	0.001	-1.208*	0.449	-0.519
Self-Reevaluation	-0.342*	0.134	-0.267	-1.156*	0.454	-0.497
Social Liberation	0.095	0.195	0.077	-1.272*	0.487	-0.526
Counter Conditioning	0.164	0.188	0.124	-1.204*	0.470	-0.531
Helping Relationships	0.065	0.090	0.052	-1.276*	0.497	-0.521
Reinforcement Management	0.069	0.090	0.056	-1.167*	0.449	-0.495
Self Liberation	0.059	0.087	0.048	-1.400*	0.548	-0.542
Stimulus Control	0.024	0.111	0.019	-1.155*	0.430	-0.500

** $p < 0.05$*

Table 3.5. Products, standard errors, 95% asymmetric confidence limits, and products of standardized coefficients for the Processes of Change that demonstrated statistical significance for both a_1 and b_1 paths

Model	Product of a_1 and b_1	s.e.	(95% Product)	Product of Std. a_1 and b_1
Mediator: Situational Temptations				
Self-Reevaluation	0.395	0.228	(0.039, 0.916)	0.133

Figure 3.1. Autoregressive mediation model II template, with Processes of Change (P) as independent variables, mediating variables (M) as mediators, and smoking outcome (Smoking) as dependent variables; at the baseline, 12-month, and 24-month time points

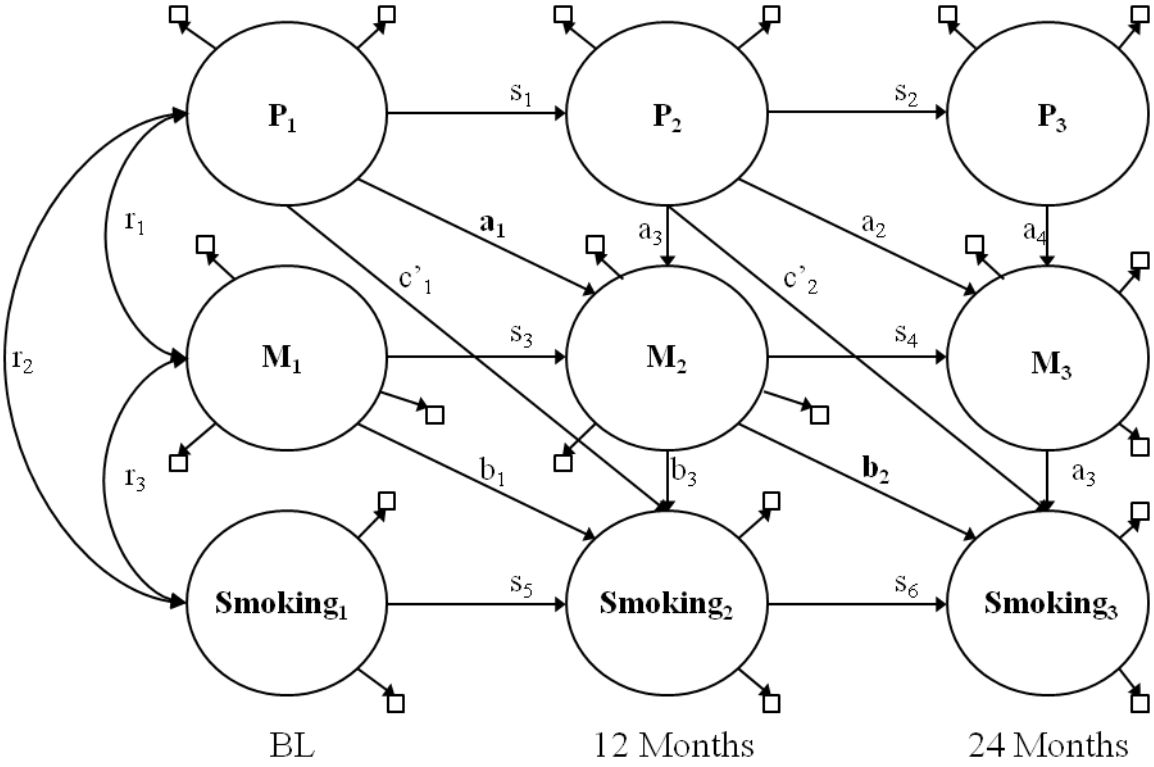
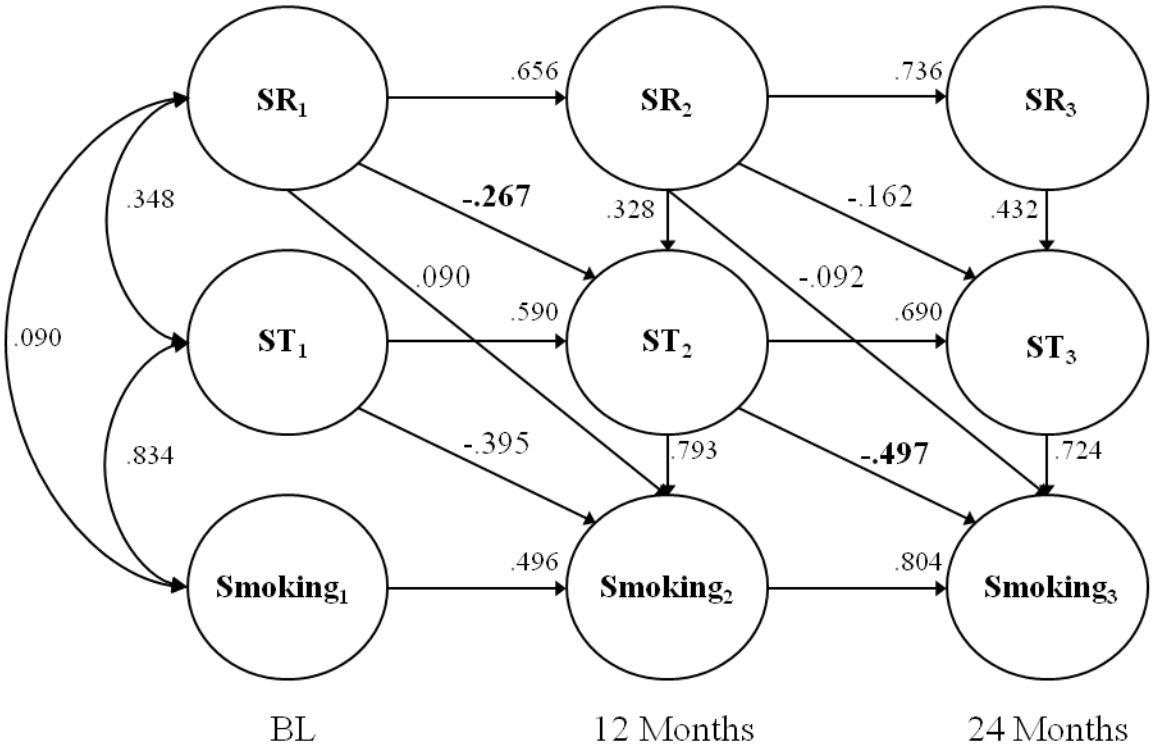


Figure 3.2. Single mediator model at PR; with Self-Reevaluation (SR) as independent variables, Situational Temptations (ST) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



Product of standardized a_1 and b_2 paths = .133

MANUSCRIPT 4

Investigating the Mechanisms of Smoking Behavior Change: Statistical Mediation Models with Multiple Mediators

Manuscript to be submitted to *Prevention Science*

Abstract

Investigating and quantifying the mechanisms that underlie behavior change is essential to understanding what drives effective interventions. Better understanding variables that explain changes in smoking behavior can provide a basis for more direct and effective smoking interventions. The present study combined data from five randomized Transtheoretical Model (TTM)-tailored intervention studies for participants in Precontemplation (PC; N = 1145) and Contemplation (C; N = 1243) at baseline. Statistical mediation analysis with autoregressive, three-wave, multiple mediator models was utilized to investigate changes in behavioral variables across three time points (baseline, 12 months, and 24 months). The ten Processes of Change for Smoking were used as independent variables, Pros of Smoking, Cons of Smoking, and Situational Temptations to Smoke were used as mediators, and a behavioral smoking outcome was used as the dependent variable across 11 multiple mediator models built from single mediator models that previously demonstrated evidence of statistical mediation. Models were assessed with structural equation modeling and consistently demonstrated good fit or better (CFI > 0.90; RMSEA < 0.10). For participants beginning intervention in PC, Consciousness Raising, Dramatic Relief, and Environmental Reevaluation were found to influence changes in smoking behavior through two mediators. These models highlight the importance of these strategies for changing behavior in interventions. Development and refinement of statistical mediation models to assess the mechanisms of behavior change are crucial to enhancing basic knowledge and informing intervention efforts.

Keywords: Statistical Mediation Analysis, Multiple Mediator Models, Smoking Cessation, Transtheoretical Model

Investigating the Mechanisms of Smoking Behavior Change: Statistical Mediation Models with Multiple Mediators

Mechanisms of behavior change explain how and why behavior change occurs. Better understanding behavioral mechanisms necessitates better understanding variables that account for observed changes in behavior. Despite the importance of mechanisms of behavior change, knowledge about these mechanisms is presently very limited (NIH, 2009; 2012). Investigating and quantifying such mechanisms that underlie behavior change is essential to understanding what drives effective interventions, and many content areas would greatly benefit from a comprehensive investigation of the mechanisms that drive behavior change.

Due to its extreme consequences, cigarette smoking represents a key health behavior that needs to be better understood. Despite decades of prevention and intervention efforts, smoking remains a critical concern for public health in the United States. Approximately 19% of U.S. adults are smokers, and while smoking prevalence rates have decreased from approximately 42% in 1965, this decrease seems to be slowing (Centers for Disease Control [CDC], 2011a; 2011b; 2012). An estimated 443,000 adults die from smoking-related illnesses every year, and smoking is estimated to cost the United States $96 billion and $97 billion in direct medical expenses and lost productivity, respectively (CDC, 2008; 2012). Given the extreme health and economic costs of smoking, improving interventions to help smokers quit is of paramount importance. Over two-thirds of smokers report that they want to quit smoking (CDC, 2011c). Better understanding the behavioral mechanisms that help smokers change their behavior will emphasize behavioral strategies to aid quitting smoking and address a major health concern.

The present study combined data from multiple intervention studies that effectively reduced smoking and utilized statistical mediation analysis to examine the mechanisms of smoking behavior change. Statistical mediation analysis is an advanced methodology that is ideal for investigating and quantifying mechanisms of behavior change.

Statistical Mediation Analysis

In general, mediation models are utilized to investigate how and why two things are related. Intermediate variables that come between independent variables and dependent variables are known as mediating variables, or mediators. A mediator acts as a third variable and represents the mechanism through which an independent variable influences an outcome (Baron & Kenny, 1986). The most basic model (MacKinnon, 2008) involves three key variables: an independent variable, X, a mediating variable, M, and a dependent variable, Y. From this simple model, additional independent variables, mediating variables, time points, and other components can be added to develop increasingly complex mediation models. In the framework of an intervention designed to change behavior, mediators are the mechanisms of behavior change. Thus, statistical mediation analysis was utilized in the present study to develop empirical models to better understand behavior change mechanisms.

A critical feature of the present series of mediation analyses is that all mediation models were longitudinal. Mediation models are also referred to as causal models, as mediators are hypothesized to cause changes in the dependent variables (and not the other way around) (Baron & Kenny, 1986). Thus, developing mediation models that demonstrate change over time requires longitudinal data to study the temporal order of change, as behavior change cannot be assumed to occur instantly. While mediation analyses can be performed with cross sectional data, the conclusions that can be drawn from such analyses are very limited (Gallob & Reichardt, 1991). Due to its limitations, cross-sectional mediation analyses should be considered both inadequate and inappropriate to study mechanisms of behavior change (Kazdin & Nock, 2003). Longitudinal mediation models require fewer assumptions, provide more accurate descriptions of the temporal order of change, and offer a more comprehensive evaluation of the mechanisms of change (MacKinnon, 2008).

The models investigated in the present study were statistical mediation models with multiple mediators, or multiple mediator models. Due to the inherent complexity of relations

among behavioral variables, statistical mediation models with multiple mediators, multiple independent variables, or multiple dependent variables almost always represent a more accurate and valid representation of statistical mediation (MacKinnon, 2008). An important assumption involved in the interpretation of results from statistical mediation analysis is the omitted variables assumption, which requires that there are no other variables related to the variables in the model that could explain the associations among the variables (MacKinnon, 2008; Meehl & Waller, 2002; Pearl, 2009). This is a challenging assumption, as inclusion of all variables that may be related to the variables of interest ranges is often impossible. Including multiple mediators in a model helps make this assumption more reasonable. Additionally, the validity of findings from statistical mediation is greatly strengthened by developing models based on theory (Pearl, 2009), as this also helps address the omitted variables assumption. In the present study, analyses were performed on data from tailored intervention studies that were based on a widely-studied model of behavior change, the Transtheoretical Model (TTM). The TTM includes a number of constructs that are ideal for investigating the mechanisms of behavior change in a mediation framework.

The Transtheoretical Model of Behavior Change

The Transtheoretical Model is an integrative framework that consists of multiple dimensions that assess different components of behavior change (Prochaska & Velicer, 1997; Velicer, Prochaska, Fava, Rossi, Redding, Laforge, & Robbins, 2000). Essentially, the TTM represents a model of how individuals adopt healthy behaviors and discontinue unhealthy ones (Brewer & Rimer, 2008). The core constructs of the TTM include stages of change, processes of change, decisional balance, and self-efficacy. Tailored interventions based on the TTM have been empirically validated and have demonstrated effectiveness for a wide variety of behaviors, including smoking (Krebs, Prochaska, & Rossi, 2010; Noar, Benac, & Harris, 2007; Velicer, Prochaska, & Redding, 2006b; Velicer, Redding, Sun, & Prochaska, 2007b).

Smoking research and the TTM have a very extensive history. Multiple components of the TTM were empirically refined with smoking as the content area, including stage of change (DiClemente et al., 1991), processes of change (Prochaska & DiClemente, 1983; Prochaska, Velicer, DiClemente, & Fava, 1988), decisional balance (Velicer, DiClemente, Prochaska & Brandenberg, 1985), and self-efficacy (Velicer, DiClemente, Rossi, & Prochaska, 1990), with longitudinal studies supporting predictive validity in some randomized and some nonrandomized studies (DiClemente et al., 1991; Prochaska, Velicer, Fava, Rossi, & Tsoh, 2001; Prochaska et al., 2004, 2005; Redding et al., 2011; Sun, Prochaska, Velicer, & LaForge, 2007; Velicer et al., 2006b, 2007b). The TTM has been applied to a wide variety of behaviors (e.g., alcohol use, exercise, diet, UV protection, mammography screening), but it has been most widely applied to smoking (Krebs et al., 2010; Noar et al., 2007).

Overview of Current Study

This is the fourth of a series of six studies that utilized statistical mediation analysis to better understand mechanisms of smoking behavior change in TTM-based studies. The first three studies focused on the development of single mediator models to investigate smokers within the three pre-action stages of smoking: Precontemplation (PC), Contemplation (C), and Preparation (PR). Statistical mediation models were developed within separate stages, rather than combining individuals across stages, because differences in stage have demonstrated nonlinear relations with the other TTM variables (Velicer, Prochaska, Rossi, & DiClemente, 1996). All models were longitudinal, with data from assessments at three time points (baseline, 12 months, and 24 months). The analytical framework was guided by the TTM, with the ten processes of change acting as independent variables, pros, cons, and self-efficacy acting as mediators, and a smoking behavior outcome acting as the dependent variable. For each stage, these variables produced a series of 30 single mediator models (10 processes * 3 mediators * 1 outcome), for a grand total of 90 single mediator models that were assessed for evidence of statistical mediation. Of the 90 single mediator models, 25 demonstrated empirical evidence of statistical mediation. These

models are summarized in Table 4.1. The present study combined these models, which demonstrated evidence of statistical mediation, to create multiple mediator models. This represents an important next step in model building.

The goal of the present study was to consolidate, refine, and extend previous findings from statistical mediation analyses with single mediator models through the development of multiple mediator models. Analyses were conducted with data from TTM-based intervention studies to determine which combinations of intervention components demonstrated empirical evidence of mediation. A total of 11 multiple mediator models, created from combinations of variables from single mediator models, were assessed.

Method

Participants

Data from five different smoking intervention studies were combined in the present study. Combining data from multiple large studies was a necessary step to create a sample size large enough to analyze the complex statistical mediation models. These studies could be combined because of a number of crucial similarities. All five studies were large, randomized, clinical trials that were successful in decreasing smoking rates. Each study collected longitudinal data, used representative, population-based sampling, and assessed all key TTM constructs (with the same items) necessary to run the mediation analyses. Only participants that received the same TTM-based smoking intervention were included in the combined sample; participants in control conditions or in other treatment groups were not included. Separate combined data sets were created to examine mediation models for participants in PC at baseline and C at baseline, as with the previously investigated single mediator models (manuscripts 1 and 2 in the present series of studies). Checking the validity of combining these studies by comparing within-study mediation models was included in a separate study (manuscript 6 in the present series of studies). The five separate studies that make up the combined sample were labeled Parent, Patient, Worksite, RDD, and Health.

Original Studies. The Parent study (Prochaska et al., 2004) involved parents of students recruited for a school-based study (N at PC=153; N at C =145). In addition to a smoking intervention, participants in this study who were at risk also received interventions on diet and sun exposure. The Patient study (Prochaska et al., 2005) involved patients from an insurance provider list (N at PC=177; N at C =287). In addition to a smoking intervention, participants in this study who were at risk also received interventions on diet, sun exposure, and mammography. The Worksite study (Velicer et al., 2004) involved employees from a sample of worksites (N at PC=77; N at C =80). In addition to a smoking intervention, participants in this study who were at risk also received interventions on diet, sun exposure, and exercise. The RDD study (Prochaska et al., 2001) involved participants from a random digit dial (RDD) sample (N at PC=565; N at C =565). This study intervened only on smoking. The Health study (Velicer, Friedman, Redding, Migneault, & Hoeppner, 2006a; Velicer, Friedman, Redding, Migneault, Hoeppner, & Prochaska, 2007a) involved participants who were smokers and who were at risk for diet and exercise in a multiple risk behavior study (N at PC=173; N at C =166). In addition to a smoking intervention, participants in this study also received interventions on diet and exercise.

Total Combined Samples. The total combined sample for participants in PC at baseline was N = 1145. Participants were 62.6% female and 92.7% white. The total combined sample for participants in C at baseline was N = 1243. Participants were 61.9% female and 92.1% white.

Intervention

All participants received a TTM-tailored smoking intervention that assessed key variables at baseline, 12 months, and 24 months. The smoking intervention was a tailored, expert system intervention, where participants received feedback matched to how they responded to TTM constructs. All interventions began with an assessment of basic demographic variables, smoking variables, and the core measures from the TTM. Interventions provided stage-matched and tailored feedback in a series of three reports at baseline, 3 months, and 6 months (RDD) or at baseline, 6 months, and 12 months (Parent, Patient, Worksite, and Health). Tailoring in these

feedback reports involved both highlighting certain strategies to change (processes of change) as well as normative and ipsative comparisons. Data from studies with different intervention schedules were combined because these two different schedules did not produce different results (Velicer et al., 2007b). Participants in all interventions also received multiple follow-up assessments. Additional details involving the expert system intervention are available elsewhere (Velicer & Prochaska, 1999; Velicer et al., 1993).

Measures

Analyses performed in the present study involved all core TTM constructs, including stage of change, processes of change, decisional balance, and self-efficacy. Additional variables, related to smoking behavior, were also used to measure a latent variable for smoking outcome.

Stage of Change. The stages of change represent the temporal dimension of TTM. The stages act as the central organizing framework of the model. Varying levels of readiness to change are represented by five stages: Precontemplation (PC), Contemplation (C), Preparation (PR), Action (A), and Maintenance (M) (DiClemente et al., 1991; Prochaska & DiClemente, 1983). Stages of change for smoking were assessed with algorithms developed to assess intentions to quit smoking (Prochaska & DiClemente, 1983). The PC stage includes participants that report being smokers and report not intending to quit in the next six months. The C stage includes participants that report being smokers and report intending to quit in the next six months. The C stage also includes participants that reported intending to quit in the next month but did not have a successful 24-hour quit attempt in the past year.

Processes of Change. The processes of change represent the independent variable dimension of the TTM. The processes involve strategies for changing one's behavior; in TTM-based interventions, the processes serve as the basis for interventions and play a critical role in tailoring the intervention to the individual. There are ten Processes of Change for Smoking (Prochaska et al., 1988). The ten processes include experiential processes, which are cognitive and emotional strategies to change behavior, and behavioral processes, which represent more

overt changes in behavior. The experiential processes include Consciousness Raising, Dramatic Relief, Environmental Reevaluation, Self-Reevaluation, and Social Liberation. The behavioral processes include Counter Conditioning, Helping Relationships, Reinforcement Management, Self Liberation, and Stimulus Control. Detailed descriptions of the Processes of Change for Smoking are available elsewhere (Prochaska et al., 1988). Participants were asked to rate how often they used each process in the last month on a 5-point Likert scale ranging from 1 (Never) to 5 (Repeatedly). Each of the processes was a latent variable measured by two items; details for the items are included in Appendix A. In the total sample, coefficient alphas for the Processes of Change for Smoking scales ranged from 0.60 to 0.84.

Decisional Balance. The decisional balance construct represents part of the intermediate variable dimension of the TTM. Decisional balance, originally adapted from Janis and Mann (1977), assess an individual's weighing of the pros and cons of engaging in a behavior. The relationship between decisional balance and the stages of change has been replicated across more than 48 different health behaviors (Hall & Rossi, 2008). The Decisional Balance Scale for Smoking is a six-item scale with three items for the Pros of Smoking and three items for the Cons of Smoking (Velicer et al., 1985). These items assess the relative importance of the pros and cons of smoking. Participants were asked to rate the importance of each item on a 5-point Likert scale ranging from 1 (Not important) to 5 (Extremely important). The Pros of Smoking and the Cons of Smoking were represented by latent variables, each measured by three items; details for the items are included in Appendix A. In the total sample, coefficient alpha was 0.70 for the Pros of Smoking and 0.66 for the Cons of Smoking.

Self-Efficacy. The self-efficacy construct represents the other part of the intermediate variable dimension of the TTM. Originally adapted from Bandura (1977), the self-efficacy construct assesses an individual's perceived ability to perform behaviors in difficult situations. Self-efficacy increases as one transitions TTM stages (Velicer et al., 1990). Improved self-efficacy predicts improved outcomes; this relationship has been repeatedly demonstrated for

smoking (Blissmer et al., 2010; Prochaska, DiClemente, Velicer, Ginpil, & Norcross, 1985; Prochaska, Velicer, DiClemente, Guadagnoli, & Rossi, 1991). In the framework of the TTM, self-efficacy either describes the confidence to engage in a healthy behavior or describes temptations to engage in an unhealthy behavior. For smoking, self-efficacy is measured by the Situational Temptations to Smoke scale (Velicer et al., 1990). The Situational Temptations describe situations that may lead some people to smoke. The instrument is a nine-item scale with three items for positive affect / social situations, three items for negative affect situations, and three items for habitual / craving situations. Participants were asked to rate how tempted to smoke they felt on a 5-point Likert scale ranging from 1 (Not at all tempted) to 5 (Extremely tempted). Details for the items are included in Appendix A. In the present study, averages of these three item content areas (e.g., positive affect / social situations) were calculated to represent Situational Temptations for Smoking with three items; a latent variable for Situational Temptations was measured by these three items. Coefficient alpha for this three-item scale was 0.78 in the total sample.

Smoking Outcome. The smoking behavioral outcome was a latent variable measured by two key items from the widely-used Fagerstrom Test for Nicotine Dependence (FTND; Fagerstrom, 1978), time to first cigarette and number of cigarettes smoked per day. These two continuous variables were converted to 5-point scales, with higher values indicating more smoking. Details for the items are included in Appendix A. Coefficient alpha for this measure was 0.75 in the total sample.

Statistical Analysis

Potential multiple mediator models were selected from the results of previous studies that investigated single mediator models (manuscripts 1, 2, and 3 in the present series of studies). There were a total of 25 single mediator models that demonstrated empirical evidence of statistical mediation (Table 4.1). Among these models that showed mediation, there were 12 single mediator models at PC, 12 single mediator models at C, and one single mediator model at

PR. Among the models at PC, there were five plausible combinations of processes with pairs of mediators, such as Consciousness Raising through the Pros of Smoking and Situational Temptations to Smoke (abbreviated CR – Pros & ST). Among the models at C, there were six plausible combinations of processes with pairs of mediators, such as Environmental Reevaluation through the Pros of Smoking and the Cons of Smoking (abbreviated ER – Pros & Cons). These 11 models are listed in Table 4.2. Another combination at C, which involved three mediators (Self-Reevaluation through the Pros of Smoking, the Cons of Smoking, and Situational Temptations) was also investigated. As there was only one model at PR, no models could be combined to create multiple mediator models.

Development of the series of multiple mediator models can be summarized by two phases of analysis. The first phase involved the creation of models that best fit the data. The second phase involved the assessment of paths within the models to search for evidence of statistical mediation.

Creation and Fit Assessment of Mediation Models. Developing models that fit the data is essential to establishing a framework for statistical mediation. Creation of the multiple mediator models was guided by the hypothesized TTM framework, where processes are the independent variables (X), decisional balance (pros, cons) and self-efficacy are mediators (M), and the smoking outcome is the dependent variable (Y).

All of the mediation models in the present study were latent variable models. The use of latent variables improves the reliability of the measures (MacKinnon, 2008). Data were available at baseline, 12 months, and 24 months, and therefore all mediation models were longitudinal, three-wave models. These models represent autoregressive mediation models (Cole & Maxwell, 2003; Gallob & Reichardt, 1991, MacKinnon, 2008). In longitudinal, autoregressive, three-wave mediation models, each variable is predicted by the same variable at an earlier wave. Due to the number of parameters being estimated in each model, and the use of latent variables, structural

equation modeling (SEM) was an ideal analytic tool to assess these mediation models (Iacobucci, Saldanha, & Deng, 2007; MacKinnon, 2008).

SEM was utilized to analyze the covariance structure, estimate regression paths, estimate error terms, and assess model fit. Missing data, which are extremely common in longitudinal studies, were estimated with maximum likelihood (ML) procedures. Using ML methods in SEM has been demonstrated to be accurate and less biased than conventional methods such as listwise or pairwise deletion (Allison, 2003; Enders & Bandalos, 2001). Previous studies that utilized single mediator models (manuscripts 1, 2, and 3 in the present series of studies) found equivalent results for models analyzed with complete case analysis and ML; thus, ML will be consistently employed for multiple mediator models to minimize bias. The following commonly-used indices were used as benchmarks to assess the model fit: likelihood ratio chi-square ($\chi 2$), Normed Fit Index (NFI), Comparative Fit Index (CFI), and Root Mean Squared Error of Approximation (RMSEA). Likelihood ratio chi-square provides a test for fit of the model based on the chi-squared distribution. The chi-square test is extremely sensitive to large sample sizes (Kline, 2005) and will always reject models with large sample sizes. Due to this issue, and the large sample sizes in the present study, chi-square values are reported but results for its associated significance test are not. For NFI and CFI, values greater than 0.90 indicate good fit and values greater than 0.95 indicate very good fit (Bentler & Bonnet, 1980; Kline, 2005). For RMSEA, values less than 0.10 indicate good fit and values less than 0.05 indicate very good fit (Browne & Cudeck, 1993). An important strategy for creating multiple mediator models was to build on the single mediator models, rather than creating entirely new models.

Assessing Statistical Mediation. Evaluating the regression paths was necessary to determining which combinations of variables actually demonstrated empirical evidence of statistical mediation. Analysis with SEM includes the estimation of regression paths among the variables. In basic three-wave autoregressive mediation models, two paths are particularly important to mediation: X at time 1 to M at time 2 (path a_1) and M at time 2 to Y at time 3 (path

b_2). Together, these two paths (a_1 * b_2) represent the mediation pathway, which is also known as the indirect effect or the intervening effect (MacKinnon, Lockwood, & Williams, 2004; Preacher & Hayes, 2008; Sobel, 1982). This basic model can be logically extended to accommodate multiple independent variables or multiple mediators. Statistical significance of each of these paths was assessed separately in SEM; if all relevant paths demonstrated statistical significance, this finding suggested that all mediation pathways may be significant. To further assess for evidence of mediation, asymmetric confidence intervals for the products of these paths were calculated (MacKinnon, 2008; Tofighi & MacKinnon, 2011). If the confidence intervals for all mediation pathways did not include zero, there was evidence that the multiple mediation model demonstrated evidence of statistical mediation. If only one of the pathways demonstrated mediation, then a single mediator model may be a more parsimonious way to describe the mediation relations.

There is no consensus on what estimates best represent effect sizes for statistical mediation analysis, and this topic represents an area that is currently under refinement (Fairchild, MacKinnon, Taborga, & Taylor, 2009; Preacher & Kelly, 2011; MacKinnon, 2008). In the present study, standardized coefficients were reported, as well as the products of the standardized coefficients (MacKinnon, 2008). These estimates help describe the magnitude of the mediated effect and will be interpreted similarly to R^2, where product absolute values of 0.01, 0.06, and 0.13 correspond to small, medium, and large effect sizes (Cohen, 1992).

Results

Creation and Fit Assessment of Mediation Models

SEM was employed with EQS 6.1 software (Bentler, 2007) to develop the multiple mediator models. Since the single mediator models successfully utilized the framework of an autoregressive mediation model II (Cole & Maxwell, 2003; MacKinnon), the multiple mediator models were developed by extending this model. The template for the basic autoregressive mediation model II is included in Figure 4.1, and the extension of the autoregressive mediation

model II, with multiple mediators, is included in Figure 4.2. There are six key characteristics to the autoregressive mediation model II (MacKinnon, 2008). First, relations are modeled one lag apart (e.g., 12 months to 24 months). Second, relations between the same variables over time are modeled to assess stability (the *s* coefficients). Third, the model includes regression paths that describe longitudinal mediation (e.g., independent variable at time 1 to mediator at time 2, independent variable at time 1 to dependent variable at time 2). Fourth, covariances among the variables at the first wave are estimated. Fifth, covariances among error terms are estimated at each wave. Sixth, relations between the independent variable and mediator, as well as mediator and dependent variable, are modeled after the first wave. This is called contemporaneous mediation; the purpose of these paths is to help account for change that occurs between the time points. As outlined above, 11 models with pairs of mediators were derived from the 25 single mediator models that demonstrated evidence of statistical mediation. One model at C, with three mediators, was also investigated.

Model Fit Statistics. The series of 11 multiple mediator models, each with one of the Processes of Change for Smoking and a pair of mediators, was successfully created. All models employed ML for missing data estimation. Fit statistics from these multiple mediator models are included in Table 4.2. For participants that began intervention in PC, all five multiple mediator models with pairs of mediators demonstrated a very good fit (CFI > 0.95, RMSEA < 0.05). For participants that began intervention in C, five out of six multiple mediator models with pairs of mediators demonstrated a very good fit (CFI > 0.95, RMSEA < 0.05). The remaining model, Self-Reevaluation through the Pros of Smoking and Situational Temptations (SR – Pros & ST), demonstrated a borderline very good fit (CFI = 0.94, RMSEA = 0.04). Overall, all 11 models demonstrated a good fit or better.

One additional model with three mediators was tested for participants in C. This three mediator model, with Self-Reevaluation through the Pros of Smoking, the Cons of Smoking, and Situational Temptations (SR – Pros & Cons & ST) is not included in Table 4.2 due to

convergence issues. Due to the increased complexity of the model with three mediators, issues with linearly dependent variables resulted in computational errors. Thus, only the pairs of mediators that make up this three mediator model were assessed (SR – Pros & Cons; SR – Pros & ST; SR – Cons & ST).

Assessing Statistical Mediation

To assess the models for evidence of statistical mediation, the longitudinal regression paths estimated in SEM were evaluated. For models with two mediators, there are four paths that were key to statistical mediation (Figure 4.2): process at baseline to mediator1 at 12 months (path $a1_1$), mediator1at 12 months to outcome at 24 months (path $b1_2$), process to mediator2 at 12 months (path $a2_1$), and mediator2 at 12 months to outcome at 24 months (path $b2_2$). Pathways within each model were assessed in two steps. First, the statistical significance of each path ($a1_1$, $b1_2$, $a2_1$, and $b2_2$) was assessed. Second, the RMediation (Tofighi & MacKinnon, 2011) application was employed to estimate asymmetric confidence intervals for the mediation pathways. For all models summarized in Tables 4.3 and 4.4, the order of the mediators in the model label represents the order of the paths. For example, in the CR – Pros & ST model, Pros of Smoking is mediator1 (path 1) and Situational Temptations is mediator2 (path 2).

Statistical Mediation with Two Mediators at PC. Unstandardized and standardized longitudinal regression paths describing the two separate mediation pathways are included in Table 4.3. Of the five multiple mediator models with pairs of mediators at PC, three models demonstrated statistical significance across both pairs of paths that make up the two mediation pathways. These models, with standardized regression paths, were: Consciousness Raising through the Pros of Smoking and Situational Temptations (CR – Pros & ST; std. $a1_1$ = -0.709, std. $b1_1$ = -0.142, std. $a2_1$ = -0.864, std. $b2_2$ = -0.239); Dramatic Relief through the Pros of Smoking and Situational Temptations (DR – Pros & ST; std. $a1_1$ = -0.733, std. $b1_1$ = -0.147, std. $a2_1$ = -0.844, std. $b2_2$ = -0.227); and Environmental Reevaluation through the Cons of Smoking and

Situational Temptations (ER – Cons & ST; std. $a1_1$ = -0.210, std. $b1_1$ = -0.128, std. $a2_1$ = -0.119, std. $b2_2$ = -0.308).

Products, asymmetric confidence intervals, and products of standardized coefficients are included in Table 4.4. All three of the previously identified models had pairs of confidence intervals that did not include zero: CR – Pros & ST (path 1 std. product = 0.101, medium-large effect; path 2 std. product = 0.206, large effect); DR – Pros & ST (path 1 std. product = 0.108, medium-large effect; path 2 std. product = 0.192, large effect); and ER – Cons & ST (path 1 std. product = 0.027, small effect; path 2 std. product = 0.037, small-medium effect). Diagrams for these models are included in Figures 4.3 through 4.5.

Statistical Mediation with Two Mediators at C. Unstandardized and standardized longitudinal regression paths describing the two separate mediation pathways are included in Table 4.3. Of the six multiple mediator models with pairs of mediators at C, none of the models demonstrated statistical significance across both pairs of paths that make up the two mediation pathways. Thus, single mediator models seem to better represent these mediation relations.

Discussion

Statistical mediation analysis with multiple mediator models was utilized to better understand relations among variables hypothesized to underlie changes in smoking behavior resulting from TTM-tailored smoking interventions. Building upon the results of single mediator models (Table 4.1), a series of 11 multiple mediator models was successfully conducted. All models were extensions of an autoregressive mediation model II (MacKinnon, 2008), had three time points (baseline, 12 months, and 24 months), and demonstrated good fit. Evidence for statistical mediation was found for three multiple mediator models where participants began intervention in PC.

Multiple Mediation Models at PC

Three Processes of Change for Smoking were found to simultaneously demonstrate evidence of statistical mediation through pairs of mediators for participants in PC at baseline.

These models included Consciousness Raising, through pros and temptations; Dramatic Relief, through pros and temptations; and Environmental Reevaluation, through cons and temptations. All three of these processes are experiential processes, which are strategies that are most important to smokers in PC (Prochaska, DiClemente, & Norcross, 1992). Consciousness Raising, which involves thinking about quitting smoking and the benefits of quitting smoking, needs to be increased in participants at PC, as these individuals need to begin to think about their smoking behavior. Dramatic Relief, which involves feeling emotionally moved by warnings about the consequences of smoking, is also very important at PC. This finding adds to the large body of evidence that warnings about the consequences of smoking, such as graphic warning labels, are effective at influencing smoking behavior (Kees, Burton, Andrews, & Kozup, 2010; Hammond, Fong, McDonald, Brown, & Cameron, 2004; Hammond, Fong, McNeill, & Cummings, 2005; Vardavas, Connolly, Karamanolis, & Kafatos, 2009). Results from the present study suggest that changes in Consciousness Raising and Dramatic Relief influence changes in smoking behavior through simultaneously influencing both the Pros of Smoking and Situational Temptations.

Environmental Reevaluation, which involves thinking about the polluting effects of smoking and the effects of smoking on the smoker's social environment, is also important to individuals in PC. Unlike Consciousness Raising and Dramatic Relief, which mostly relate to thinking about how smoking impacts the individual, Environmental Reevaluation involves thinking about others. The standardized paths associated with Environmental Reevaluation were much smaller than those for the other processes in multiple mediator models. However, while only Consciousness Raising and Dramatic Relief are associated with medium and large effects, all three of these processes should be considered very important to changing smoking behavior, as they were able to simultaneously influence multiple mediators.

Multiple Mediation Models at C

Of the six potential multiple mediator models at C, none of the Processes of Change were found to simultaneously demonstrate evidence of statistical mediation through two mediators.

Previous analyses with single mediator models identified 12 combinations of processes and mediators that demonstrated evidence of statistical mediation (Table 4.1), and these single mediator models appear to best represent the data at C. While there are many advantages to multiple mediator models, the models become dramatically more complex as additional variables are added. The strength of relations among variables often decreases when additional variables are introduced; this is particularly relevant for the mediators, which are correlated. Thus, for one of the Processes of Change for Smoking to demonstrate mediation through two mediators, the relations among these variables must be very strong. Thus, the finding that none of the multiple mediator models at C demonstrate mediation through two mediators does not reduce the importance of the single mediator models; rather, the finding emphasizes the importance of the processes that were able to influence multiple mediators at PC.

Comparisons to Results from Single Mediator Models

The series of multiple mediator models was comprised of combinations of variables that demonstrated evidence of statistical mediation in single mediator models. However, in many of the multiple mediator models, only one of the mediators was found to demonstrate mediation. In these cases, estimates suggest that one of the mediators accounted for most of the change, and the other was found to be less important. Among models at PC and C, including both the Pros of Smoking and the Cons of Smoking as mediators in a single model resulted in a lack of mediation through the pathway associated with the Cons (Table 4.3). More specifically, the path from the Cons to the smoking outcome was substantially reduced in magnitude. This finding suggests that the Pros of Smoking at 12 months were more related to smoking behavior than the Cons of Smoking at 12 months. Among models at C, including both Situational Temptations and another mediator (Pros or Cons) was similarly problematic. Potentially due to the high correlation between temptations and smoking outcome, the path from Situational Temptations to smoking outcome was consistently the strongest.

The multiple mediator models that involved Consciousness Raising and Dramatic Relief, for individuals starting intervention in PC, demonstrated strong evidence of statistical mediation. An unexpected finding from these models was that the magnitudes of the mediated effects, as described by the individual standardized regression paths and products of standardized regression paths, actually increased from their respective single mediator models. This was particularly true for Dramatic Relief, which demonstrated comparatively small effects in single mediator models (std. product through Pros of Smoking = 0.060, std. product through Situational Temptations = 0.034), but demonstrated larger effects in the multiple mediator model (std. product through Pros of Smoking = 0.108, std. product through Situational Temptations = 0.194). Thus, there appears to be a relationship akin to synergy in models where these two Processes of Change for Smoking simultaneously influence the Pros of Smoking and Situational Temptations. These unique relations could be explored in future studies.

The paths that made up the mediation pathways, process at baseline to mediators at 12 months ($a1_1$ and $a2_1$) and mediators at 12 months to smoking outcome at 24 months ($b1_2$ and $b2_2$), were the focus of the present study, but there were many other paths that revealed important information about statistical mediation. Two additional paths that were important to mediation were the two direct effects, process at baseline to smoking outcome at 12 months (c'_1) and process at 12 months to smoking outcome at 24 months (c'_2). These paths describe the relations from the independent variables to the dependent variables, adjusted for the effects of the mediators. In statistical mediation models, effective mediators should result in comparatively small direct effects, and in the present study, the direct effects were consistently very small. Examples of these relations are included in Figures 4.3 through 4.5.

Limitations

The use of secondary data represents the biggest limitation to the present study. Limitations from the original studies impacted the statistical mediation analyses in a number of ways. First, while the combined datasets for PC and C included a wide range of participants, the

diversity of the sample was suboptimal; each of the five studies was primarily white, and the combined samples for PC and C were approximately 92% white. A substantially more diverse sample, with more participants of different races and different ethnicities, would greatly improve the validity of these statistical mediation models. Additionally, a truly international sample would further increase the generalizability of the results, and the results would better represent the true underlying mechanisms of smoking behavior change.

Second, the details of the tailored interventions produced some limitations. The five original studies that comprised the combined sample all utilized stage-matched tailoring; participants in different stages received feedback that emphasized certain processes of change. For example, participants in PC typically received feedback that highlighted experiential processes of change, such as Consciousness Raising, Environmental Reevaluation, and Self-Reevaluation. Since participants did not receive an equal amount of feedback for each of the ten processes, the tailoring may have impacted process use differentially. Determining the extent to which the tailoring influenced the relations among the processes and the mediators was impossible because control groups could not be included in the analyses. All analyses were conducted on participants that were in treatment groups, and the lack of control groups created multiple important limitations. Analyses could not be performed because the processes of change were not assessed in the control conditions of the original studies (to reduce contamination due to measurement). Comparisons among the treatment and control groups would have revealed important intervention effects as well as additional insight into the mechanisms of smoking behavior change. If the mediation relations described in the present study truly represent mechanisms of behavior change for smoking, control groups would demonstrate similar relations, but with lower magnitudes, as TTM interventions are thought to accelerate naturalistic processes of behavior change (Prochaska & Velicer, 1997; Velicer et al., 2000; Velicer et al., 2006b). Additionally, evidence for causality was limited due to the lack of data from control groups;

comparing data from randomized treatment and control conditions would greatly enhance evidence of causal relations.

Third, measurement issues from the original studies resulted in some limitations. The lack of data for the processes of change in control groups, as discussed above, was the biggest limitation. Another limitation was that the short forms of all measures were utilized. For example, each of the processes of change was measured by two items. In the intervention studies, this was necessary to prevent the assessments from being unreasonably long. For the present study, measures with more items would have been very beneficial. Coefficient alpha values for many measures, including the processes of change, pros, and cons were often low (but still within an acceptable range); internal consistency for each measure would be improved with additional items. Additional items for measures may have also improved the predictive power of constructs. Relations among processes of change and mediators, as well as processes of change and smoking outcomes, were typically smaller in magnitude than the relations among mediators and smoking outcomes. This finding may be partially explained by the two-item scales for the processes. Additional items for each of the processes could increase the magnitude of relations, and this could result in more evidence for statistical mediation.

Smoking outcome was an important component of all mediation models and was associated with some limitations. Unlike other constructs in the present study (e.g., Consciousness Raising, Cons of Smoking), which were previously validated in past studies, the smoking outcome was specifically developed to perform statistical mediation models for smoking. The two items that measured the latent variable for smoking outcome, time to first cigarette and cigarettes per day, have been used extremely often in smoking intervention studies, but are typically not combined as a latent variable. Thus, the measure could benefit from more vigorous psychometric testing in the future. As with the other scales, the smoking outcome would be strengthened by additional items. One type of item that would be particularly beneficial for the smoking outcome would be an item that reflected stage progression. The present smoking

outcome may not have fully captured subtle changes for participants in PC due to the content of the items (time to first cigarette, cigarettes per day). Someone in PC may not change on these overt behaviors, but may progress to C, which predicts future change (Blissmer et al., 2010). Regardless, the smoking outcome variable performed very well in the present study as well as in all single mediator models, and it correlated highly with Situational Temptations to Smoke, which has been used in the past as a smoking outcome variable (Velicer et al., 1996).

Fourth, timing issues related to both measurement and intervention were also limitations. At least three time points were necessary to run the longitudinal mediation models; baseline, 12 months, and 24 months were selected because all original five studies had full assessments at these time points. However, in all of these studies the intervention was complete by the 12-month time point. Thus, the most dramatic changes may have occurred between baseline and 12 months, but these could not be fully captured in the mediation models. The changes from 12 months to 24 months involved the lasting effects of the intervention. The mediation models in the present study described changes over a wide time frame, and they would be improved with additional time points.

All of these areas of limitations could be addressed with a study specifically designed to test mediational hypotheses. An ideal TTM-tailored intervention study to test mediation would (1) recruit a large, diverse sample; (2) collect data for all TTM constructs for both treatment and control groups; (3) utilize scales for TTM constructs that had more than two items each and include extra items to assess smoking behavior; and (4) perform full assessments (at least) every six months. With the data produced by such a study, the resulting mediation models would provide very compelling evidence of the mechanisms of smoking behavior change.

An important limitation of the present study, likely unrelated to the use of secondary data, involved the signs of the regression paths in the mediation models. In many instances, the signs of regression paths were opposite from what was expected. The longitudinal regression paths in particular had some unusual patterns. Notably, the paths from the mediator at 12 months to the

smoking outcome at 24 months ($b1_2$ and $b2_2$) in the mediation pathways were consistently found to be negative. This unexpected finding suggests the presence of suppressor effects (Kline, 2005; MacKinnon, 2008; Velicer, 1978). Paths with unexpectedly negative signs were also found in the evaluation of the single mediator models (manuscripts 1, 2, and 3 in the present series of studies). Suppressor effects are common in longitudinal structural equation models and are even more common when latent variables are involved (Maassen & Bakker, 2001).

The unexpectedly negative b_2 paths likely represent examples of negative suppression, where the signs are reversed due to the presence of other, stronger positive predictors of smoking outcome at 24 months. For example, consider the Pros of Smoking; for a b_2 path from the Pros of Smoking at 12 months to smoking at 24 months, the other, stronger predictors included smoking outcome at 12 months and the Pros of Smoking at 24 months. Further evidence of suppression was found through modification of the models. When one of the strong predictors of smoking outcome at 24 months was deleted from the model (either the smoking outcome at 12 months or the Pros of Smoking at 24 months), the sign of the longitudinal mediation path b_2 flipped from negative to positive. This suggested that b_2 was negative simply because of the other predictors. Due to suppression effects, the signs of regression paths need to be interpreted with caution. Instead, effect sizes should be the emphasis of interpretation. The magnitude of each regression path, as described by the standardized coefficients, is very important. The effect size of the overall mediation pathway, calculated from the product of the standardized coefficients, is also more important to describing mediation than the signs of any individual paths.

Future Directions for Analysis

An important validity check for the statistical mediation models developed in the present study will be whether the estimates are consistent across subsamples. For example, different age groups may demonstrate different patterns. In the framework of SEM, multiple subsamples can be compared simultaneously with factorial invariance procedures (Meredith, 1993). A separate

study (manuscript 6 in the present series of studies) will evaluate factorial invariance across a series of subgroup variables, including age, education level, gender, race, and original study.

Conclusions

The present study built statistical mediation models with multiple mediators from the results of single mediator models. The development of models with multiple mediators helped further highlight mediating mechanisms that drove the observed changes in smoking behavior in the five TTM-based smoking interventions that contributed to the combined data sets. For individuals beginning intervention in PC, Consciousness Raising and Dramatic relief were found to be essential strategies for driving decreases in smoking through influencing both the Pros of Smoking and Situational Temptations to Smoke. This insight into the mechanisms of smoking behavior change has the potential to lead to the improvement and refinement of smoking cessation interventions. Modern, computerized interventions can adapt to make intervention contacts as relevant as possible by tailoring to individuals to focus on which behavioral mechanisms are the most important to changing behavior. By focusing on the most important Processes of Change for Smoking, interventions have the empirical evidence-based potential to become more direct and effective.

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Table 4.1. Summary of models that demonstrated evidence of statistical mediation (abbreviations used in other tables are included in parentheses)

Independent Variable	Mediator	Product of Std. a1 and b2
Baseline Stage: Precontemplation		
Consciousness Raising (CR)	Pros of Smoking (Pros)	0.105
Dramatic Relief (DR)	Pros of Smoking (Pros)	0.060
Self-Reevaluation (SR)	Pros of Smoking (Pros)	0.081
Social Liberation (SO)	Pros of Smoking (Pros)	0.108
Environmental Reevaluation (ER)	Cons of Smoking (Cons)	0.045
Self-Reevaluation (SR)	Cons of Smoking (Cons)	0.089
Social Liberation (SO)	Cons of Smoking (Cons)	0.130
Helping Relationships (HR)	Cons of Smoking (Cons)	0.034
Self Liberation (SL)	Cons of Smoking (Cons)	0.040
Consciousness Raising (CR)	Situational Temptations (ST)	0.087
Dramatic Relief (DR)	Situational Temptations (ST)	0.034
Environmental Reevaluation (ER)	Situational Temptations (ST)	0.033
Baseline Stage: Contemplation		
Consciousness Raising (CR)	Pros of Smoking (Pros)	0.090
Dramatic Relief (DR)	Pros of Smoking (Pros)	0.074
Environmental Reevaluation (ER)	Pros of Smoking (Pros)	0.040
Self-Reevaluation (SR)	Pros of Smoking (Pros)	0.078
Social Liberation (SO)	Pros of Smoking (Pros)	0.062
Counter Conditioning (CC)	Pros of Smoking (Pros)	-0.111
Environmental Reevaluation (ER)	Cons of Smoking (Cons)	0.025
Self-Reevaluation (SR)	Cons of Smoking (Cons)	0.055
Social Liberation (SO)	Cons of Smoking (Cons)	0.063
Self-Reevaluation (SR)	Situational Temptations (ST)	0.084
Counter Conditioning (CC)	Situational Temptations (ST)	-0.053
Stimulus Control (SC)	Situational Temptations (ST)	-0.052
Baseline Stage: Preparation		
Self-Reevaluation (SR)	Situational Temptations (ST)	0.133

Table 4.2. Fit indices for multiple mediator models, PC and C

Model	N	χ^2	(df)	NFI	CFI	RMSEA	(90% RMSEA)
Baseline Stage: Precontemplation							
CR – Pros & ST	1145	1639.116	(344)	0.931	0.961	0.032	(0.029, 0.035)
DR – Pros & ST	1145	1726.737	(344)	0.934	0.963	0.032	(0.029, 0.035)
ER – Cons & ST	1145	850.800	(344)	0.986	1.000	0.000	-
SO – Pros & Cons	1145	596.821	(344)	0.986	1.000	0.000	-
SR – Pros & Cons	1145	743.123	(344)	0.983	1.000	0.000	-
Baseline Stage: Contemplation							
CC – Pros & ST	1243	1633.866	(344)	0.935	0.962	0.033	(0.030, 0.036)
ER – Pros & Cons	1243	760.652	(344)	0.984	1.000	0.000	-
SO – Pros & Cons	1243	628.295	(344)	0.986	1.000	0.000	-
SR – Pros & Cons	1243	758.883	(344)	0.980	1.000	0.000	-
SR – Pros & ST	1243	1997.220	(344)	0.919	0.943	0.041	(0.039, 0.044)
SR – Cons & ST	1243	824.721	(344)	0.978	1.000	0.000	-

- Lower confidence limit negative, interval not calculated

Table 4.3. Multiple mediator models: unstandardized (with standard errors) and standardized longitudinal regression paths describing the mediation pathway; Processes of Change at baseline to mediator at 12 months ($a1_1$ & $a2_1$) and mediator at 12 months to smoking outcome at 24 months ($b1_2$ & $b2_2$)

Model	**$a1_1$** **$a2_1$**	**s.e.** **s.e.**	**Std. $a1_1$** **Std. $a2_1$**	**$b1_2$** **$b2_2$**	**s.e.** **s.e.**	**Std. $b1_2$** **Std. $b2_2$**
Baseline Stage: Precontemplation						
CR – Pros & ST	-1.658*	0.394	-0.709	-0.204*	0.091	-0.142
	-1.880*	0.555	-0.864	-0.255*	0.093	-0.239
DR – Pros & ST	-1.697*	0.379	-0.733	-0.215*	0.092	-0.147
	-1.822*	0.531	-0.844	-0.250*	0.031	-0.227
ER – Cons & ST	-0.316*	0.116	-0.210	-0.165*	0.080	-0.128
	-0.159*	0.063	-0.119	-0.447*	0.124	-0.308
SO – Pros & Cons	-1.105*	0.312	-0.622	-0.313*	0.092	-0.366
	-1.938*	0.722	-0.868	-0.094	0.058	-0.138
SR – Pros & Cons	-0.326*	0.104	-0.217	-0.391*	0.106	-0.381
	-0.873*	0.319	-0.454	-0.093	0.075	-0.116
Baseline Stage: Contemplation						
CC – Pros & ST	2.491*	0.512	0.743	-0.052	0.118	-0.076
	1.929	4.683	0.904	-0.084	0.085	-0.277
ER – Pros & Cons	-0.161*	0.074	-0.109	-0.378*	0.091	-0.336
	-0.284*	0.088	-0.201	-0.064	0.065	-0.054
SO – Pros & Cons	-0.406*	0.123	-0.247	-0.369*	0.099	-0.361
	-0.647*	0.214	-0.378	-0.015	0.068	-0.015
SR – Pros & Cons	-0.525*	0.146	-0.319	-0.320*	0.084	-0.315
	-0.611*	0.197	-0.375	-0.052	0.066	-0.051
SR – Pros & ST	-1.799*	0.266	-0.925	-0.092	0.066	-0.083
	-0.724*	0.158	-0.620	-0.675*	0.172	-0.369
SR – Cons & ST	-0.601*	0.192	-0.371	-0.011	0.073	-0.009
	-0.430*	0.108	-0.333	-0.505*	0.124	-0.323

* $p < 0.05$

Table 4.4. Products, standard errors, 95% asymmetric confidence limits, and products of standardized longitudinal regression paths for the Processes of Change that demonstrated statistical significance for all paths ($a1_1$, $a2_1$, $b1_2$, $b2_2$)

Model	Product of $a1_1$ and $b1_2$	s.e.	(95% Product)	Product of Std. $a1_1$ and $b1_2$
	Product of $a2_1$ and $b2_2$	**s.e.**	**(95% Product)**	**Product of Std. $a2_1$ and $b2_2$**
Baseline Stage: Precontemplation				
CR – Pros & ST	0.338	0.175	(0.038, 0.721)	0.101
	0.479	0.231	(0.101, 0.996)	0.206
DR – Pros & ST	0.365	0.180	(0.054, 0.756)	0.108
	0.456	0.145	(0.187, 0.757)	0.192
ER – Cons & ST	0.052	0.033	(0.001, 0.128)	0.027
	0.071	0.035	(0.013, 0.150)	0.037

Figure 4.1. Autoregressive mediation model II template, with Processes of Change (P) as independent variables, mediating variables (M) as mediators, and smoking outcome (Smoking) as dependent variables; at the baseline, 12-month, and 24-month time points

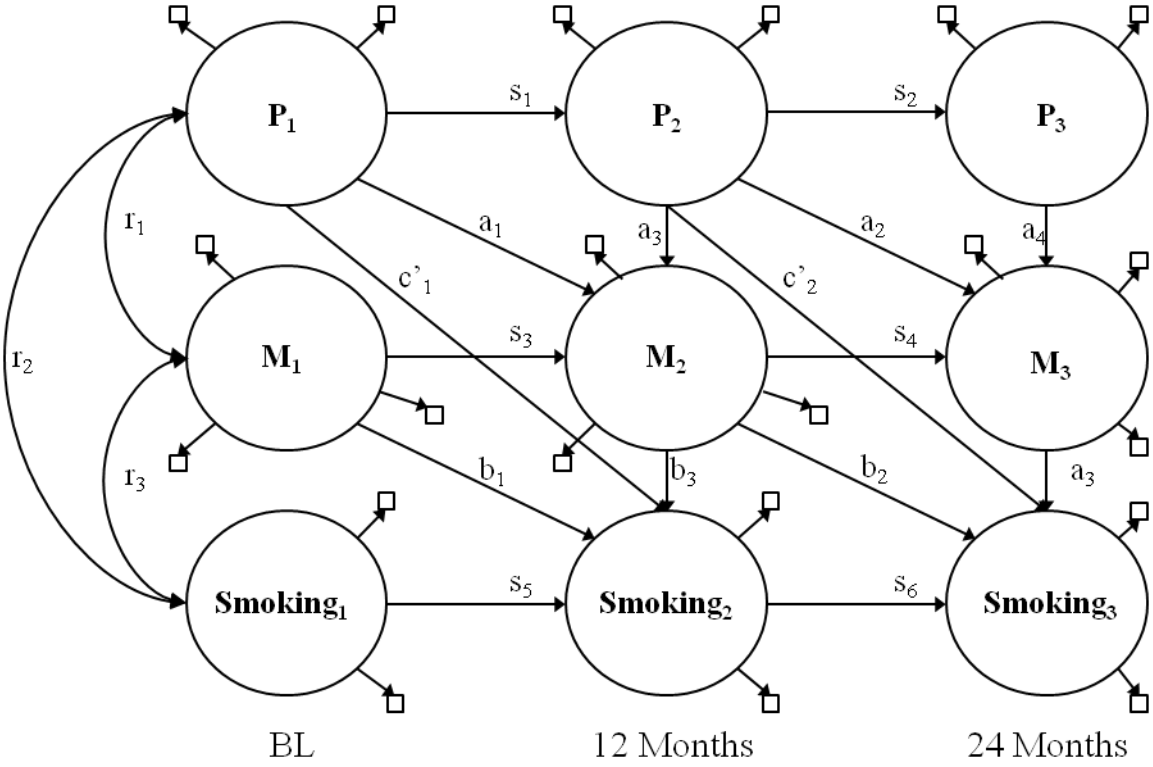


Figure 4.2. Autoregressive mediation model II template, modified to include multiple mediator variables, with Processes of Change (P) as independent variables, mediating variables (M) as mediators, and smoking outcome (Smoking) as dependent variables; at the baseline, 12-month, and 24-month time points (item loadings, stability paths, contemporaneous mediation paths, and covariances not labeled to simplify diagram)

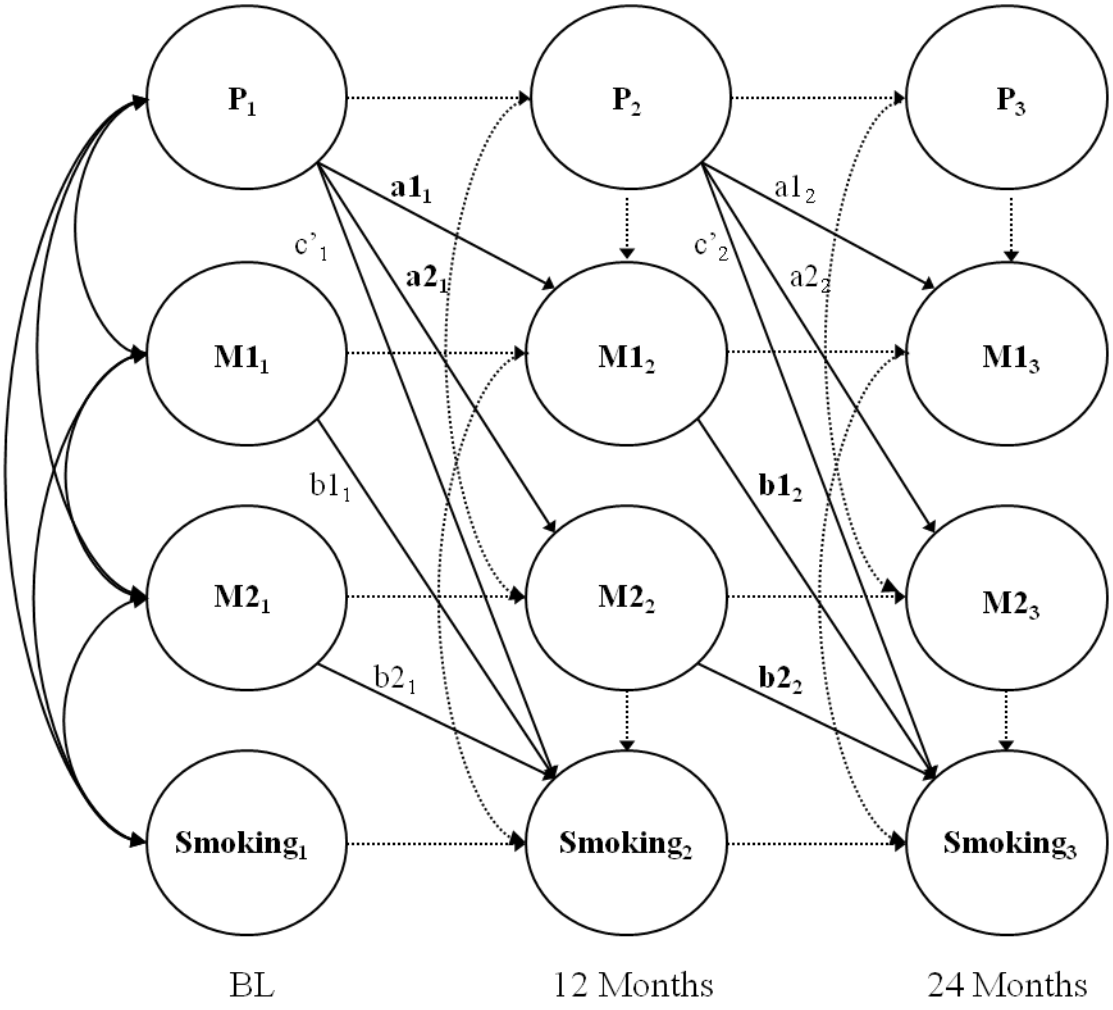
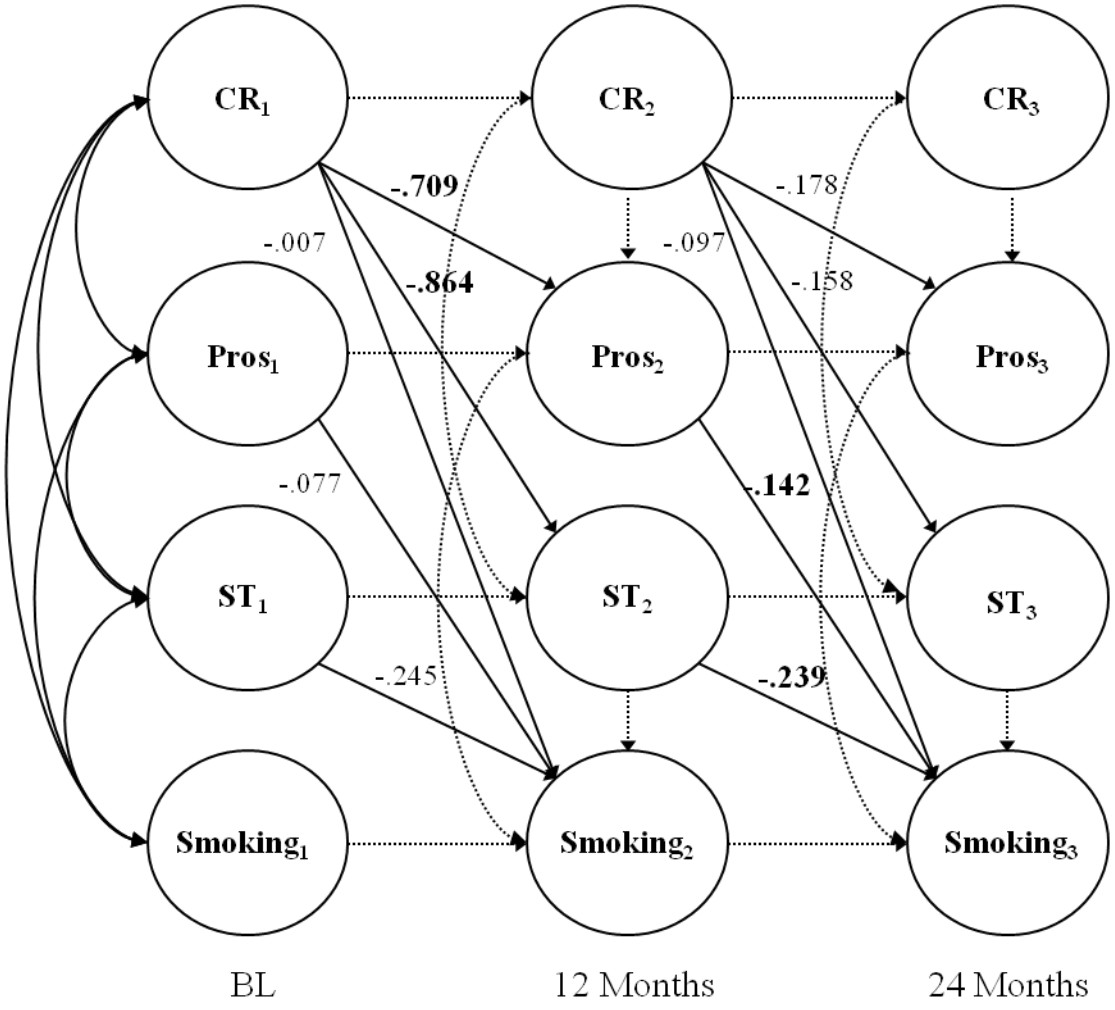


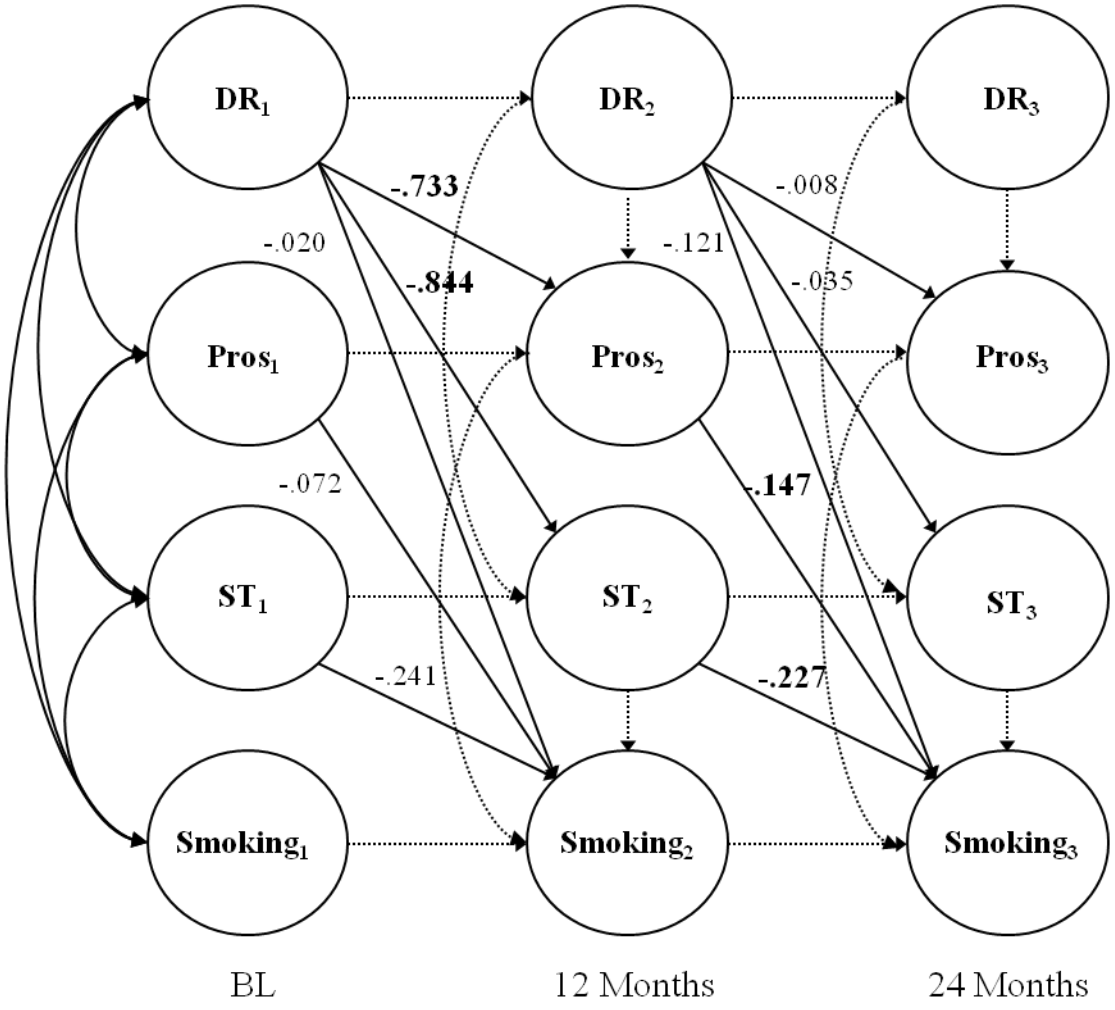
Figure 4.3. Multiple mediator model at PC; with Consciousness Raising (CR) as independent variables, Pros of Smoking (Pros) and Situational Temptations (ST) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



Product of standardized $a1_1$ and $b1_2$ paths = .101

Product of standardized $a2_1$ and $b2_2$ paths = .206

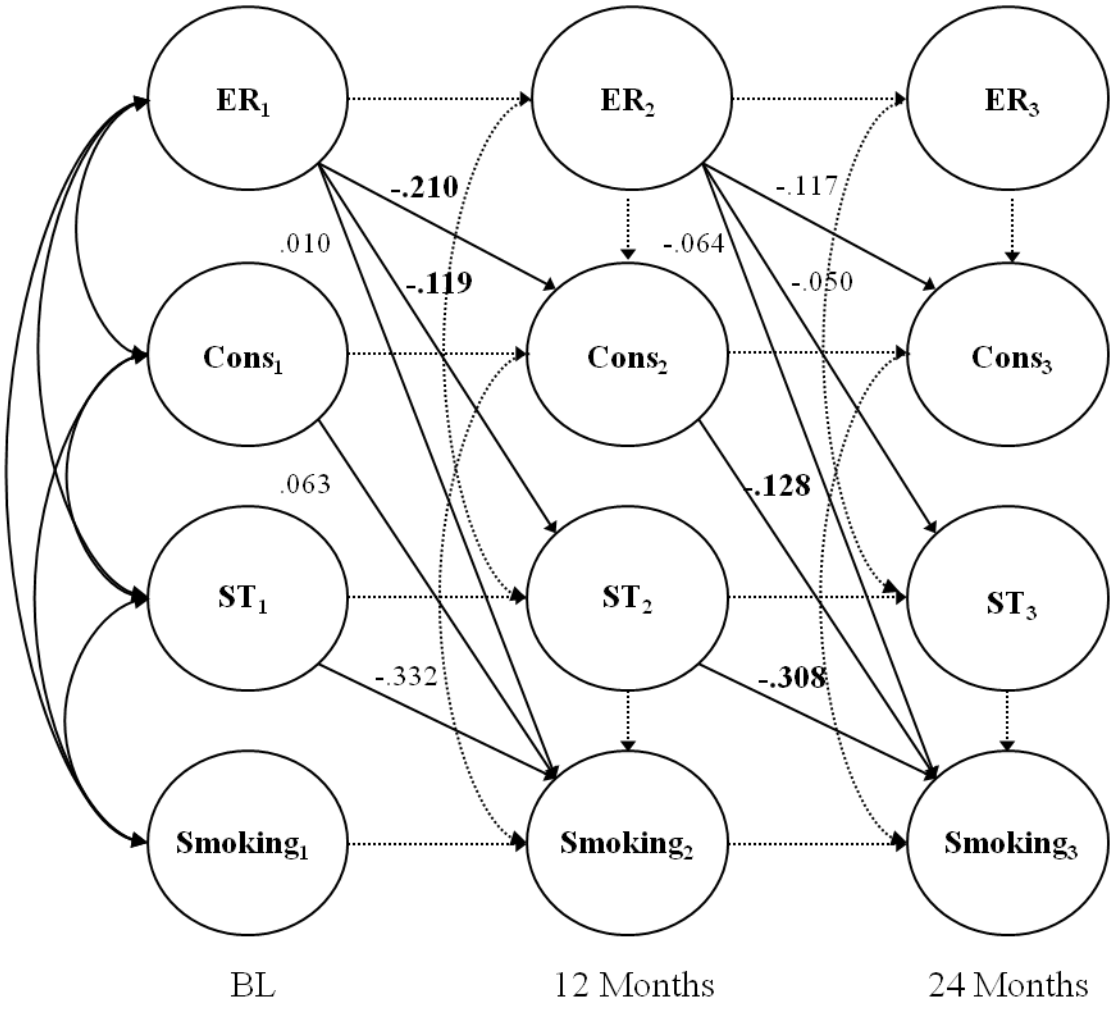
Figure 4.4. Multiple mediator model at PC; with Dramatic Relief (DR) as independent variables, Pros of Smoking (Pros) and Situational Temptations (ST) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



Product of standardized $a1_1$ and $b1_2$ paths = .108

Product of standardized $a2_1$ and $b2_2$ paths = .192

Figure 4.5. Multiple mediator model at PC; with Environmental Reevaluation (ER) as independent variables, Cons of Smoking (Cons) and Situational Temptations (ST) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



Product of standardized $a1_1$ and $b1_2$ paths = .027

Product of standardized $a2_1$ and $b2_2$ paths = .037

MANUSCRIPT 5

Investigating the Mechanisms of Smoking Behavior Change: Statistical Mediation Models with Multiple Processes of Change

Manuscript to be submitted to *Prevention Science*

Abstract

Investigating and quantifying the mechanisms that underlie behavior change is essential to understanding what drives effective interventions. Better understanding variables that explain changes in smoking behavior can provide a basis for more direct and effective interventions. The present study combined data from five randomized Transtheoretical Model (TTM)-tailored intervention studies for participants in Precontemplation (PC; N = 1145) and Contemplation (C; N = 1243) at baseline. Statistical mediation analysis with autoregressive, three-wave, multiple independent variable (IV) models was utilized to investigate changes in behavioral variables across three time points (baseline, 12 months, and 24 months). The ten Processes of Change for Smoking were used as independent variables, Pros of Smoking, Cons of Smoking, and Situational Temptations to Smoke were used as mediators, and a behavioral smoking outcome was used as the dependent variable across 37 multiple IV models built from single mediator models that previously demonstrated evidence of statistical mediation. Models were assessed with structural equation modeling and consistently demonstrated a very good fit (CFI > 0.95; RMSEA < 0.05). Multiple IV models demonstrated evidence of mediation through all three mediators. For participants beginning intervention in PC and C, Consciousness Raising, Dramatic Relief, Environmental Reevaluation, Social Liberation, and Self-Reevaluation were found to be essential processes for driving decreases in smoking. For participants in C, Counter Conditioning and Stimulus Control were also important. These models highlight the value of these strategies for changing behavior in interventions. Development and refinement of statistical mediation models to assess the mechanisms of behavior change are crucial to enhancing basic knowledge and informing intervention efforts.

Keywords: Statistical Mediation Analysis, Smoking Cessation, Transtheoretical Model, Processes of Change

Investigating the Mechanisms of Smoking Behavior Change: Statistical Mediation Models with Multiple Processes of Change

Mechanisms of behavior change explain how and why behavior change occurs. Better understanding behavioral mechanisms necessitates better understanding variables that account for observed changes in behavior. Despite the importance of mechanisms of behavior change, knowledge about these mechanisms is presently very limited (NIH, 2009; 2012). Investigating and quantifying such mechanisms that underlie behavior change is essential to understanding what drives effective interventions, and many content areas would greatly benefit from a comprehensive investigation of the mechanisms that drive behavior change.

Due to its extreme consequences, cigarette smoking represents a key health behavior that needs to be better understood. Despite decades of prevention and intervention efforts, smoking remains a critical concern for public health in the United States. Approximately 19% of U.S. adults are smokers, and while smoking prevalence rates have decreased from approximately 42% in 1965, this decrease seems to be slowing (Centers for Disease Control [CDC], 2011a; 2011b; 2012). An estimated 443,000 adults die from smoking-related illnesses every year, and smoking is estimated to cost the United States $96 billion and $97 billion in direct medical expenses and lost productivity, respectively (CDC, 2008; 2012). Given the extreme health and economic costs of smoking, improving interventions to help smokers quit is of paramount importance. Over two-thirds of smokers report that they want to quit smoking (CDC, 2011c). Better understanding the behavioral mechanisms that help smokers change their behavior will emphasize behavioral strategies to aid quitting smoking and address a major health concern.

The present study combined data from multiple intervention studies that effectively reduced smoking and utilized statistical mediation analysis to examine the mechanisms of smoking behavior change. Statistical mediation analysis is an advanced methodology that is ideal for investigating and quantifying mechanisms of behavior change.

Statistical Mediation Analysis

In general, mediation models are utilized to investigate how and why two things are related. Intermediate variables that come between independent variables and dependent variables are known as mediating variables, or mediators. A mediator acts as a third variable and represents the mechanism through which an independent variable influences an outcome (Baron & Kenny, 1986). The most basic model (MacKinnon, 2008) involves three key variables: an independent variable, X, a mediating variable, M, and a dependent variable, Y. From this simple model, additional independent variables, mediating variables, time points, and other components can be added to develop increasingly complex mediation models. In the framework of an intervention designed to change behavior, mediators are the mechanisms of behavior change. Thus, statistical mediation analysis was utilized in the present study to develop empirical models to better understand behavior change mechanisms.

A critical feature of the present series of mediation analyses is that all mediation models were longitudinal. Mediation models are also referred to as causal models, as mediators are hypothesized to cause changes in the dependent variables (and not the other way around) (Baron & Kenny, 1986). Thus, developing mediation models that demonstrate change over time requires longitudinal data to study the temporal order of change, as behavior change cannot be assumed to occur instantly. While mediation analyses can be performed with cross sectional data, the conclusions that can be drawn from such analyses are very limited (Gallob & Reichardt, 1991). Due to its limitations, cross-sectional mediation analyses should be considered both inadequate and inappropriate to study mechanisms of behavior change (Kazdin & Nock, 2003). Longitudinal mediation models require fewer assumptions, provide more accurate descriptions of the temporal order of change, and offer a more comprehensive evaluation of the mechanisms of change (MacKinnon, 2008).

The models investigated in the present study were statistical mediation models with multiple independent variables, or multiple independent variable (IV) models. Due to the inherent

complexity of relations among behavioral variables, statistical mediation models with multiple mediators, multiple independent variables, or multiple dependent variables almost always represent a more accurate and valid representation of statistical mediation (MacKinnon, 2008). An important assumption involved in the interpretation of results from statistical mediation analysis is the omitted variables assumption, which requires that there are no other variables related to the variables in the model that could explain the associations among the variables (MacKinnon, 2008; Meehl & Waller, 2002; Pearl, 2009). This is a challenging assumption, as inclusion of all variables that may be related to the variables of interest ranges is often impossible. Including multiple independent variables in a model helps make this assumption more reasonable. Additionally, the validity of findings from statistical mediation is greatly strengthened by developing models based on theory (Pearl, 2009), as this also helps address the omitted variables assumption. In the present study, analyses were performed on data from tailored intervention studies that were based on a widely-studied model of behavior change, the Transtheoretical Model (TTM). The TTM includes a number of constructs that are ideal for investigating the mechanisms of behavior change in a mediation framework.

The Transtheoretical Model of Behavior Change

The Transtheoretical Model is an integrative framework that consists of multiple dimensions that assess different components of behavior change (Prochaska & Velicer, 1997; Velicer, Prochaska, Fava, Rossi, Redding, Laforge, & Robbins, 2000). Essentially, the TTM represents a model of how individuals adopt healthy behaviors and discontinue unhealthy ones (Brewer & Rimer, 2008). The core constructs of the TTM include stages of change, processes of change, decisional balance, and self-efficacy. Tailored interventions based on the TTM have been empirically validated and have demonstrated effectiveness for a wide variety of behaviors, including smoking (Krebs, Prochaska, & Rossi, 2010; Noar, Benac, & Harris, 2007; Velicer, Prochaska, & Redding, 2006b; Velicer, Redding, Sun, & Prochaska, 2007b).

Smoking research and the TTM have a very extensive history. Multiple components of the TTM were empirically refined with smoking as the content area, including stage of change (DiClemente et al., 1991), processes of change (Prochaska & DiClemente, 1983; Prochaska, Velicer, DiClemente, & Fava, 1988), decisional balance (Velicer, DiClemente, Prochaska & Brandenberg, 1985), and self-efficacy (Velicer, DiClemente, Rossi, & Prochaska, 1990), with longitudinal studies supporting predictive validity in some randomized and some nonrandomized studies (DiClemente et al., 1991; Prochaska, Velicer, Fava, Rossi, & Tsoh, 2001; Prochaska et al., 2004, 2005; Redding et al., 2011; Sun, Prochaska, Velicer, & LaForge, 2007; Velicer et al., 2006b, 2007b). The TTM has been applied to a wide variety of behaviors (e.g., alcohol use, exercise, diet, UV protection, mammography screening), but it has been most widely applied to smoking (Krebs et al., 2010; Noar et al., 2007).

Overview of Current Study

This is the fifth of a series of six studies that utilized statistical mediation analysis to better understand mechanisms of smoking behavior change in TTM-based studies. The first three studies focused on the development of single mediator models to investigate smokers within the three pre-action stages of smoking: Precontemplation (PC), Contemplation (C), and Preparation (PR). Statistical mediation models were developed within separate stages, rather than combining individuals across stages, because differences in stage have demonstrated nonlinear relations with the other TTM variables (Velicer, Prochaska, Rossi, & DiClemente, 1996). All models were longitudinal, with data from assessments at three time points (baseline, 12 months, and 24 months). The analytical framework was guided by the TTM, with the ten processes of change acting as independent variables, pros, cons, and self-efficacy acting as mediators, and a smoking behavior outcome acting as the dependent variable. For each stage, these variables produced a series of 30 single mediator models (10 processes * 3 mediators * 1 outcome), for a grand total of 90 single mediator models that were assessed for evidence of statistical mediation. Of the 90 single mediator models, 25 demonstrated empirical evidence of statistical mediation. These

models are summarized in Table 5.1. The fourth study involved building on the results of the single mediator models to develop multiple mediator models. The present study built on the results of the single mediator models in a different way to develop models with multiple independent variables.

The goal of the present study was to consolidate, refine, and extend previous findings from statistical mediation analyses with single mediator models through the development of multiple IV models. Analyses were conducted with data from TTM-based intervention studies to determine which combinations of intervention components demonstrated empirical evidence of mediation. A final total of 37 multiple IV models, created from combinations of variables from single mediator models, were assessed.

Method

Participants

Data from five different smoking intervention studies were combined in the present study. Combining data from multiple large studies was a necessary step to create a sample size large enough to analyze the complex statistical mediation models. These studies could be combined because of a number of crucial similarities. All five studies were large, randomized, clinical trials that were successful in decreasing smoking rates. Each study collected longitudinal data, used representative, population-based sampling, and assessed all key TTM constructs (with the same items) necessary to run the mediation analyses. Only participants that received the same TTM-based smoking intervention were included in the combined sample; participants in control conditions or in other treatment groups were not included. Separate combined data sets were created to examine mediation models for participants in PC at baseline and C at baseline, as with the previously investigated single mediator models (manuscripts 1 and 2 in the present series of studies). Checking the validity of combining these studies by comparing within-study mediation models was included in a separate study (manuscript 6 in the present series of studies). The five

separate studies that make up the combined sample were labeled Parent, Patient, Worksite, RDD, and Health.

Original Studies. The Parent study (Prochaska et al., 2004) involved parents of students recruited for a school-based study (N at PC=153; N at C =145). In addition to a smoking intervention, participants in this study who were at risk also received interventions on diet and sun exposure. The Patient study (Prochaska et al., 2005) involved patients from an insurance provider list (N at PC=177; N at C =287). In addition to a smoking intervention, participants in this study who were at risk also received interventions on diet, sun exposure, and mammography. The Worksite study (Velicer et al., 2004) involved employees from a sample of worksites (N at PC=77; N at C =80). In addition to a smoking intervention, participants in this study who were at risk also received interventions on diet, sun exposure, and exercise. The RDD study (Prochaska et al., 2001) involved participants from a random digit dial (RDD) sample (N at PC=565; N at C =565). This study intervened only on smoking. The Health study (Velicer, Friedman, Redding, Migneault, & Hoeppner, 2006a; Velicer, Friedman, Redding, Migneault, Hoeppner, & Prochaska, 2007a) involved participants who were smokers and who were at risk for diet and exercise in a multiple risk behavior study (N at PC=173; N at C =166). In addition to a smoking intervention, participants in this study also received interventions on diet and exercise.

Total Combined Samples. The total combined sample for participants in PC at baseline was N = 1145. Participants were 62.6% female and 92.7% white. The total combined sample for participants in C at baseline was N = 1243. Participants were 61.9% female and 92.1% white.

Intervention

All participants received a TTM-tailored smoking intervention that assessed key variables at baseline, 12 months, and 24 months. The smoking intervention was a tailored, expert system intervention, where participants received feedback matched to how they responded to TTM constructs. All interventions began with an assessment of basic demographic variables, smoking variables, and the core measures from the TTM. Interventions provided stage-matched and

tailored feedback in a series of three reports at baseline, 3 months, and 6 months (RDD) or at baseline, 6 months, and 12 months (Parent, Patient, Worksite, and Health). Tailoring in these feedback reports involved both highlighting certain strategies to change (processes of change) as well as normative and ipsative comparisons. Data from studies with different intervention schedules were combined because these two different schedules did not produce different results (Velicer et al., 2007b). Participants in all interventions also received multiple follow-up assessments. Additional details involving the expert system intervention are available elsewhere (Velicer & Prochaska, 1999; Velicer et al., 1993).

Measures

Analyses performed in the present study involved all core TTM constructs, including stage of change, processes of change, decisional balance, and self-efficacy. Additional variables, related to smoking behavior, were also used to measure a latent variable for smoking outcome.

Stage of Change. The stages of change represent the temporal dimension of TTM. The stages act as the central organizing framework of the model. Varying levels of readiness to change are represented by five stages: Precontemplation (PC), Contemplation (C), Preparation (PR), Action (A), and Maintenance (M) (DiClemente et al., 1991; Prochaska & DiClemente, 1983). Stages of change for smoking were assessed with algorithms developed to assess intentions to quit smoking (Prochaska & DiClemente, 1983). The PC stage includes participants that report being smokers and report not intending to quit in the next six months. The C stage includes participants that report being smokers and report intending to quit in the next six months. The C stage also includes participants that reported intending to quit in the next month but did not have a successful 24-hour quit attempt in the past year.

Processes of Change. The processes of change represent the independent variable dimension of the TTM. The processes involve strategies for changing one's behavior; in TTM-based interventions, the processes play a critical role in tailoring the intervention to the individual. There are ten Processes of Change for Smoking (Prochaska et al., 1988). The ten

processes include experiential processes, which are cognitive and emotional strategies to change behavior, and behavioral processes, which represent more overt changes in behavior. The experiential processes include Consciousness Raising, Dramatic Relief, Environmental Reevaluation, Self-Reevaluation, and Social Liberation. The behavioral processes include Counter Conditioning, Helping Relationships, Reinforcement Management, Self Liberation, and Stimulus Control. Detailed descriptions of the Processes of Change for Smoking are available elsewhere (Prochaska et al., 1988). Participants were asked to rate how often they used each process in the last month on a 5-point Likert scale ranging from 1 (Never) to 5 (Repeatedly). Each of the processes was a latent variable measured by two items; details for the items are included in Appendix A. In the total sample, coefficient alphas for the Processes of Change for Smoking scales ranged from 0.60 to 0.84.

Decisional Balance. The decisional balance construct represents part of the intermediate variable dimension of the TTM. Decisional balance, originally adapted from Janis and Mann (1977), assess an individual's weighing of the pros and cons of engaging in a behavior. The relationship between decisional balance and the stages of change has been replicated across more than 48 different health behaviors (Hall & Rossi, 2008). The Decisional Balance Scale for Smoking is a six-item scale with three items for the Pros of Smoking and three items for the Cons of Smoking (Velicer et al., 1985). These items assess the relative importance of the pros and cons of smoking. Participants were asked to rate the importance of each item on a 5-point Likert scale ranging from 1 (Not important) to 5 (Extremely important). The Pros of Smoking and the Cons of Smoking were represented by latent variables, each measured by three items; details for the items are included in Appendix A. In the total sample, coefficient alpha was 0.70 for the Pros of Smoking and 0.66 for the Cons of Smoking.

Self-Efficacy. The self-efficacy construct represents the other part of the intermediate variable dimension of the TTM. Originally adapted from Bandura (1977), the self-efficacy construct assesses an individual's perceived ability to perform behaviors in difficult situations.

Self-efficacy increases as one transitions TTM stages (Velicer et al., 1990). Improved self-efficacy predicts improved outcomes; this relationship has been repeatedly demonstrated for smoking (Blissmer et al., 2010; Prochaska, DiClemente, Velicer, Ginpil, & Norcross, 1985; Prochaska, Velicer, DiClemente, Guadagnoli, & Rossi, 1991). In the framework of the TTM, self-efficacy either describes the confidence to engage in a healthy behavior or describes temptations to engage in an unhealthy behavior. For smoking, self-efficacy is measured by the Situational Temptations to Smoke scale (Velicer et al., 1990). The Situational Temptations describe situations that may lead some people to smoke. The instrument is a nine-item scale with three items for positive affect / social situations, three items for negative affect situations, and three items for habitual / craving situations. Participants were asked to rate how tempted to smoke they felt on a 5-point Likert scale ranging from 1 (Not at all tempted) to 5 (Extremely tempted). Details for the items are included in Appendix A. In the present study, averages of these three item content areas (e.g., positive affect / social situations) were calculated to represent Situational Temptations for Smoking with three items; a latent variable for Situational Temptations was measured by these three items. Coefficient alpha for this three-item scale was 0.78 in the total sample.

Smoking Outcome. The smoking behavioral outcome was a latent variable measured by two key items from the widely-used Fagerstrom Test for Nicotine Dependence (FTND; Fagerstrom, 1978), time to first cigarette and number of cigarettes smoked per day. These two continuous variables were converted to 5-point scales, with higher values indicating more smoking. Details for the items are included in Appendix A. Coefficient alpha for this measure was 0.75 in the total sample.

Statistical Analysis

Potential multiple mediator models were selected from the results of previous studies that investigated single mediator models (manuscripts 1, 2, and 3 in the present series of studies). There were a total of 25 single mediator models that demonstrated empirical evidence of

statistical mediation (Table 5.1). Among these models that showed mediation, there were 12 single mediator models at PC, 12 single mediator models at C, and one single mediator model at PR. Among the models at PC, there were 18 plausible combinations of pairs of processes through mediators, such as Consciousness Raising and Dramatic Relief through the Pros of Smoking (abbreviated CR & DR – Pros). Among the models at C, there were 21 plausible combinations of processes with pairs of mediators, such as Self-Reevaluation and Stimulus Control through Situational Temptations (abbreviated SR & SC – ST). Model building began with pairs of processes, and then plausible triplets of processes were tested. As there was only one model at PR, no models could be combined to create multiple mediator models.

Development of the series of multiple IV models can be summarized by two phases of analysis. The first phase involved the creation of models that best fit the data. The second phase involved the assessment of paths within the models to search for evidence of statistical mediation.

Creation and Fit Assessment of Mediation Models. Developing models that fit the data is essential to establishing a framework for statistical mediation. Creation of the multiple IV models was guided by the hypothesized TTM framework, where processes are the independent variables (X), decisional balance (pros, cons) and self-efficacy are mediators (M), and the smoking outcome is the dependent variable (Y). All of the mediation models in the present study were latent variable models. The use of latent variables improves the reliability of the measures (MacKinnon, 2008). Data were available at baseline, 12 months, and 24 months, and therefore all mediation models were longitudinal, three-wave models. These models represent autoregressive mediation models (Cole & Maxwell, 2003; Gallob & Reichardt, 1991, MacKinnon, 2008). In longitudinal, autoregressive, three-wave mediation models, each variable is predicted by the same variable at an earlier wave. Due to the number of parameters being estimated in each model, and the use of latent variables, structural equation modeling (SEM) was an ideal analytic tool to assess these mediation models (Iacobucci, Saldanha, & Deng, 2007; MacKinnon, 2008).

SEM was utilized to analyze the covariance structure, estimate regression paths, estimate error terms, and assess model fit. Missing data, which are extremely common in longitudinal studies, were estimated with maximum likelihood (ML) procedures. Using ML methods in SEM has been demonstrated to be accurate and less biased than conventional methods such as listwise or pairwise deletion (Allison, 2003; Enders & Bandalos, 2001). Previous studies that utilized single mediator models (manuscripts 1, 2, and 3 in the present series of studies) found equivalent results for models analyzed with complete case analysis and ML; thus, ML will be consistently employed for multiple mediator models to minimize bias. The following commonly-used indices were used as benchmarks to assess the model fit: likelihood ratio chi-square ($\chi 2$), Normed Fit Index (NFI), Comparative Fit Index (CFI), and Root Mean Squared Error of Approximation (RMSEA). Likelihood ratio chi-square provides a test for fit of the model based on the chi-squared distribution. The chi-square test is extremely sensitive to large sample sizes (Kline, 2005) and will always reject models with large sample sizes. Due to this issue, and the large sample sizes in the present study, chi-square values are reported but results for its associated significance test are not. For NFI and CFI, values greater than 0.90 indicate good fit and values greater than 0.95 indicate very good fit (Bentler & Bonnet, 1980; Kline, 2005). For RMSEA, values less than 0.10 indicate good fit and values less than 0.05 indicate very good fit (Browne & Cudeck, 1993). An important strategy for creating multiple IV models was to build on the single mediator models, rather than creating entirely new models.

Assessing Statistical Mediation. Evaluating the regression paths was necessary to determining which combinations of variables actually demonstrated empirical evidence of statistical mediation. Analysis with SEM includes the estimation of regression paths among the variables. In basic three-wave autoregressive mediation models, two paths are particularly important to mediation: X at time 1 to M at time 2 (path a_1) and M at time 2 to Y at time 3 (path b_2). Together, these two paths ($a_1 * b_2$) represent the mediation pathway, which is also known as the indirect effect or the intervening effect (MacKinnon, Lockwood, & Williams, 2004; Preacher

& Hayes, 2008; Sobel, 1982). This basic model can be logically extended to accommodate multiple independent variables or multiple mediators. Statistical significance of each of these paths was assessed separately in SEM; if all paths demonstrated statistical significance, this finding suggests that all mediation pathways may be significant. To further assess for evidence of mediation, asymmetric confidence intervals for the products of these paths were calculated (MacKinnon, 2008; Tofighi & MacKinnon, 2011). If the confidence intervals for all mediation pathways did not include zero, there was evidence that the multiple IV model demonstrated evidence of statistical mediation. If only one of the pathways demonstrated mediation, then a single mediator model may be a more parsimonious way to describe the mediation relations.

There is no consensus on what estimates best represent effect sizes for statistical mediation analysis, and this topic represents an area that is currently under refinement (Fairchild, MacKinnon, Taborga, & Taylor, 2009; Preacher & Kelly, 2011; MacKinnon, 2008). In the present study, standardized coefficients for $a1_1$, $a2_1$, and b_2 were reported, as well as the products of the standardized coefficients (MacKinnon, 2008). These estimates help describe the magnitude of the mediated effect and will be interpreted similarly to R^2, where product absolute values of 0.01, 0.06, and 0.13 correspond to small, medium, and large effect sizes (Cohen, 1992).

Results

Creation and Fit Assessment of Mediation Models

SEM was employed with EQS 6.1 software (Bentler, 2007) to develop the multiple IV models. Since single mediator models, as well as multiple mediator models, successfully utilized the framework of an autoregressive mediation model II (Cole & Maxwell, 2003; MacKinnon), the multiple IV models were also developed by extending this model. The template for the basic autoregressive mediation model II is included in Figure 5.1, and the extension of the autoregressive mediation model II, with multiple IVs, is included in Figure 5.2. There are six key characteristics to the autoregressive mediation model II (MacKinnon, 2008). First, relations are modeled one lag apart (e.g., 12 months to 24 months). Second, relations between the same

variables over time are modeled to assess stability (the *s* coefficients). Third, the model includes regression paths that describe longitudinal mediation (e.g., independent variable at time 1 to mediator at time 2, independent variable at time 1 to dependent variable at time 2). Fourth, covariances among the variables at the first wave are estimated. Fifth, covariances among error terms are estimated at each wave. Sixth, relations between the independent variable and mediator, as well as mediator and dependent variable, are modeled after the first wave. This is called contemporaneous mediation; the purpose of these paths is to help account for change that occurs between the time points. As outlined above, 39 models (18 from PC, 21 from C) with pairs of IVs were derived from the 25 single mediator models. Based on the results of these models, a model with a triplet of processes at C was also tested.

Model Fit Statistics. The series of multiple IV models, each with a pair of the Processes of Change for Smoking and a one mediator, was successfully created. All models employed ML for missing data estimation. Fit statistics from these multiple IV models are included in Table 5.2. For participants that began intervention in PC, all 18 multiple IV models with pairs of processes demonstrated a very good fit (CFI > 0.95, RMSEA < 0.05). For participants that began intervention in C, all 21 multiple IV models with pairs of processes demonstrated a very good fit (CFI > 0.95, RMSEA < 0.05). Table 5.2 does not include three of these pairs (CR & SR – Pros, CR & CC – Pros, and SR & CC – Pros), because these combinations of processes all demonstrated mediation (see below), and they were able to be successfully combined into a multiple IV model with three IVs. This complex model, CR & SR & CC – Pros, demonstrated a very good fit.

Assessing Statistical Mediation

To assess the models for evidence of statistical mediation, the longitudinal regression paths estimated in SEM were evaluated. For models with two processes, there are three paths that were key to statistical mediation (Figure 5.2): process1 at baseline to mediator at 12 months (path $a1_1$), process2 at baseline to mediator at 12 months (path $a2_1$), and mediator at 12 months to

outcome at 24 months (b_2). The two mediation pathways consist of these pairs of paths ($a1_1$ * b_2 and $a2_1$ * b_2). Pathways were tested within each model in two steps. First, the statistical significance of each path ($a1_1$, $a2_1$, and b_2) was assessed. Second, for models that were found to have statistical significance for both pairs of paths, the RMediation (Tofighi & MacKinnon, 2011) application was employed to estimate asymmetric confidence intervals for the mediation pathways. For models with three IVs, there is another pathway involving process3 at baseline to mediator at 12-months, $a3_1$. For all models summarized in Tables 5.3 and 5.4, the order of the IVs in the model label represents the order of the paths. For example, in the CR & SO - Pros model, Consciousness Raising is process1 (path 1) and Social Liberation is process 2 (path 2). Diagrams are included for models where all mediation paths demonstrated a medium or greater effect size.

Statistical Mediation with Two IVs at PC. Unstandardized and standardized longitudinal regression paths describing the separate mediation pathways are included in Table 5.3. Only multiple IV models that demonstrated statistical significance across both pairs of paths that make up the mediation pathway are listed. Of the 18 multiple IV models with pairs of IVs at PC, four models demonstrated statistical significance across all paths. These models, with standardized regression paths, were: Consciousness Raising and Social Liberation through the Pros of Smoking (CR & SO – Pros; std. $a1_1$ = -0.199, std. $a2_1$ = -0.189, std. b_2 = -0.425); Dramatic Relief and Social Liberation through the Pros of Smoking (DR & SO – Pros; std. $a1_1$ = -0.124, std. $a2_1$ = -0.227, std. b_2 = -0.428); Self-Reevaluation and Social Liberation through the Pros of Smoking (SR & SO – Pros; std. $a1_1$ = -0.149, std. $a2_1$ = -0.201, std. b_2 = -0.456); and Environmental Reevaluation and Social Liberation through the Cons of Smoking (ER & SO – Cons; std. $a1_1$ = -0.184, std. $a2_1$ = -0.385, std. b_2 = -0.212).

Products, asymmetric confidence intervals, and products of standardized coefficients are included in Table 5.4. All four of the previously identified models had pairs of confidence intervals that did not include zero: CR & SO – Pros (path 1 std. product = 0.083, medium effect; path 2 std. product = 0.079, medium effect; Figure 5.3); DR & SO – Pros (path 1 std. product =

0.051, small-medium effect; path 2 std. product = 0.094, medium effect); SR & SO – Pros (path 1 std. product = 0.068, medium effect; path 2 std. product = 0.092, medium effect; Figure 5.4); and ER & SO – Cons (path 1 std. product = 0.039, small-medium effect; path 2 = std. product = 0.082, medium effect).

Statistical Mediation with Two or Three IVs at C. Unstandardized and standardized longitudinal regression paths describing the separate mediation pathways are included in Table 5.3. Only multiple IV models that demonstrated statistical significance across both pairs of paths that make up the mediation pathway are listed. Of the 21 multiple IV models with pairs of IVs at C, seven models demonstrated statistical significance across all paths. Three of these models were further combined into a model with three processes, thus reducing the number of final models to five. These models, with standardized regression paths, were: Consciousness Raising, Self-Reevaluation, and Counter Conditioning through the Pros of Smoking (CR & SR & CC – Pros; std. $a1_1$ = -0.252, std. $a2_1$ = -0.160, std. $a3_1$ = 0.291, std. b_2 = -0.582); Dramatic Relief and Counter Conditioning through the Pros of Smoking (DR & CC – Pros; std. $a1_1$ = -0.314, std. $a2_1$ = 0.322, std. b_2 = -0.494); Environmental Reevaluation and Counter Conditioning through the Pros of Smoking (ER & CC – Pros; std. $a1_1$ = -0.159, std. $a2_1$ = 0.297, std. b_2 = -0.471); Self-Reevaluation and Social Liberation through the Pros of Smoking (SR & SO – Pros; std. $a1_1$ = -0.224, std. $a2_1$ = -0.133, std. b_2 = -0.349); and Self-Reevaluation and Stimulus Control through Situational Temptations (SR & SC – ST; std. $a1_1$ = -0.294, std. $a2_1$ = 0.190, std. b_2 = -0.304).

Products, asymmetric confidence intervals, and products of standardized coefficients are included in Table 5.4. All five of the previously identified models had pairs of confidence intervals that did not include zero: CR & SR & CC – Pros (path 1 std. product = 0.147, large effect; path 2 std. product = 0.093, medium effect; path 3 std. product = -0.169, large effect; Figure 5.5); DR & CC – Pros (path 1 std. product = 0.155, large effect; path 2 std. product = -0.159, large effect; Figure 5.6); ER & CC – Pros (path 1 std. product = 0.075, medium effect; path 2 std. product = -0.140, large effect; Figure 5.7); SR & SO – Pros (path 1 std. product =

0.078, medium effect; path 2 std. product = 0.046, small-medium effect); and SR & SC – ST (path 1 std. product = 0.089, medium effect; path 2 std. product = -0.058, medium effect; Figure 5.8).

Discussion

Statistical mediation analysis with multiple IV models was utilized to better understand relations among variables hypothesized to underlie changes in smoking behavior resulting from TTM-tailored smoking interventions. Building upon the results of single mediator models (Table 5.1), a series of 37 multiple IV models was successfully conducted. All models were extensions of an autoregressive mediation model II (MacKinnon, 2008), had three time points (baseline, 12 months, and 24 months), and demonstrated very good fit. Evidence for statistical mediation was found with nine final models for participants in both PC and C at baseline.

Multiple IV Models at PC

Four pairs of Processes of Change for Smoking were found to demonstrate evidence of statistical mediation for participants in PC at baseline. All four of these pairs included Social Liberation, which involves observing how changes in society are benefitting nonsmokers. This process of change was previously identified as having the largest mediation effects among single mediator models (Table 5.1; manuscript 1 in the present series of studies). Evidence for the importance of Social Liberation is strengthened by its ability to influence smoking behavior in models where it is competing with another independent variable. This finding is consistent with evidence supporting the growing ubiquity of legislation to regulate smoking, such as banning smoking in public places, restaurants, and workplaces (He, Vupputuri, Allen, Prerost, Hughest, & Whelton, 1999; Meyers, Neuberger, & He, 2009; Pell et al., 2008; Sargent, Shepard, & Glantz, 2004). The other processes of change, paired with Social Liberation, which demonstrated mediation were Consciousness Raising, Dramatic Relief, Self-Reevaluation, and Environmental Reevaluation. These processes were previously identified as being important to driving changes in smoking behavior in both single mediator models and multiple mediator models. Additionally,

these five processes are the five experiential processes, which are strategies that are hypothesized by TTM to be most important to smokers in PC (Prochaska, DiClemente, & Norcross, 1992). Results from the present study suggest that these five Processes of Change for Smoking are among the most important for participants beginning intervention in PC.

Multiple IV Models at C

Five combinations of Processes of Change for Smoking were found to demonstrate evidence of statistical mediation for participants in C at baseline. Like with the multiple IV models at PC, there were some commonalities across models. Three of these combinations involved Self-Reevaluation, and three involved Counter Conditioning. These processes demonstrated some of the largest mediation effects in the single mediator models (Table 5.1; manuscript 2 in the present series of studies), and they remained important in the multiple IV models. Self-Reevaluation, in particular, appears to be very important for individuals beginning an intervention in C. This process involves individuals feeling upset or disappointed in themselves for their smoking. When combined with other processes of change, Self-Reevaluation demonstrates mediation through both the Pros of Smoking (with Social Liberation and the combination of Consciousness Raising and Counter Conditioning) and Situational Temptations to Smoke (with Social Liberation). Cognitions involved with Self-Reevaluation, including disappointment in oneself and developing a new self-image, appear to influence smoking behavior.

Counter Conditioning also demonstrated evidence of statistical mediation in three multiple IV models. This strategy involves replacing smoking with other behaviors. Counter conditioning demonstrated mediation through only one mediator, the Pros of Smoking (with Dramatic Relief, Environmental Reevaluation, and the combination of Consciousness Raising and Counter Conditioning). Unlike Self-Reevaluation, which is an experiential process, Counter Conditioning is behavioral; the Processes of Change for Smoking associated with statistical mediation in multiple IV models at C include both experiential and behavioral processes. The

experiential processes are used mostly in early stages, while the behavioral processes are used mostly in later stages (DiClemente et al., 1995; Prochaska, DiClemente, & Norcross, 1992). Results from the multiple IV models suggest that intervening on two of the behavioral processes, Counter Conditioning and Stimulus Control, may be helpful for participants in stages as early as Contemplation.

In addition to the processes that demonstrated mediation in multiple combinations of variables, other variables deserve attention due to evidence of large mediated effects. Effect sizes quantify the strength of the mediational relations and are pivotal to interpreting the overall evidence for mediation. Consciousness Raising, Dramatic Relief, and Counter Conditioning were very important to individuals in C. Based on the estimates from standardized regression paths, and the products of these paths, these three processes had a large impact on smoking behavior through the Pros of Smoking. In fact, these effects were larger than any of the effects at PC. Thus, smoking cessation interventions should include materials that target thinking about quitting smoking and the benefits of quitting smoking (Consciousness Raising), warnings about the consequences of smoking (Dramatic Relief), and Counter Conditioning techniques.

Overall Patterns

There was some overlap among the combinations of processes at PC and C that demonstrated evidence of mediation, and these recurring processes appear to be particularly important to behavior change. Five different Processes of Change for Smoking comprised the multiple IV models for individuals in PC at baseline, and all five of these were also important for individuals in C (see Table 5.3). One of the combinations (SR & SO – Pros) was actually found in both stages. The additional two processes that were found for individuals in C, Counter Conditioning and Stimulus Control, are both behavioral processes. This finding fits with hypotheses from the TTM, as the behavioral processes should be the least important for precontemplators.

In general, successful multiple IV models consisted of Processes of Change for Smoking that previously demonstrated strong evidence of statistical mediation in single mediator models (Table 5.1). For example, at PC, the largest mediation effects through the Pros of Smoking involved Consciousness Raising and Social Liberation. When these were put into the same model, they produced a multiple IV model with two strong mediation pathways. However, for some variables, this pattern was not as predictable. One instance of this involves Consciousness Raising and Dramatic Relief for individuals beginning intervention in C. Results from single mediator models suggested that these two processes had medium sized effects. However, when put into the same model, the magnitude of the paths associated with Dramatic Relief decreased substantially. The result was the opposite when Dramatic Relief was combined with Counter Conditioning (Table 5.4); the product of the standardized paths increased from 0.074 (single mediator model) to 0.155 (multiple IV). Such results emphasize the complexity of these mediation models and the potential for unexpected relations among variables. Future studies with different samples, different behaviors, or even simulated data, could help explain such patterns.

The three paths that made up the mediation pathways, processes at baseline to mediator at 12 months ($a1_1$ and $a2_1$) and mediator at 12 months to smoking outcome at 24 months (b_2), were the focus of the present study, but there were many other paths that revealed important information about statistical mediation. Four additional paths that were important to mediation were the direct effects, processes at baseline to smoking outcome at 12 months ($c1'_1$ and $c2'_1$) and processes at 12 months to smoking outcome at 24 months ($c1'_2$ and $c2'_2$). These paths describe the relations from the independent variables to the dependent variables, adjusted for the effects of the mediators. In statistical mediation models, effective mediators should result in comparatively small direct effects, and in the present study, the direct effects were consistently very small. Examples of these relations are included in Figures 5.3 through 5.8.

Limitations

The use of secondary data represents the biggest limitation to the present study. Limitations from the original studies impacted the statistical mediation analyses in a number of ways. First, while the combined datasets for PC and C included a wide range of participants, the diversity of the sample was suboptimal; each of the five studies was primarily white, and the combined samples for PC and C were approximately 92% white. A substantially more diverse sample, with more participants of different races and different ethnicities, would greatly improve the validity of these statistical mediation models. Additionally, a truly international sample would further increase the generalizability of the results, and the results would better represent the true underlying mechanisms of smoking behavior change.

Second, the details of the tailored interventions produced some limitations. The five original studies that comprised the combined sample all utilized stage-matched tailoring; participants in different stages received feedback that emphasized certain processes of change. For example, participants in PC typically received feedback that highlighted experiential processes of change, such as Consciousness Raising, Environmental Reevaluation, and Self-Reevaluation. Since participants did not receive an equal amount of feedback for each of the ten processes, the tailoring may have impacted process use differentially. Determining the extent to which the tailoring influenced the relations among the processes and the mediators was impossible because control groups could not be included in the analyses. All analyses were conducted on participants that were in treatment groups, and the lack of control groups created multiple important limitations. Analyses could not be performed because the processes of change were not assessed in the control conditions of the original studies (to reduce contamination due to measurement). Comparisons among the treatment and control groups would have revealed important intervention effects as well as additional insight into the mechanisms of smoking behavior change. If the mediation relations described in the present study truly represent mechanisms of behavior change for smoking, control groups would demonstrate similar relations, but with lower magnitudes, as TTM interventions are thought to accelerate naturalistic processes

of behavior change (Prochaska & Velicer, 1997; Velicer et al., 2000; Velicer et al., 2006b). Additionally, evidence for causality was limited due to the lack of data from control groups; comparing data from randomized treatment and control conditions would greatly enhance evidence of causal relations.

Third, measurement issues from the original studies resulted in some limitations. The lack of data for the processes of change in control groups, as discussed above, was the biggest limitation. Another limitation was that the short forms of all measures were utilized. For example, each of the processes of change was measured by two items. In the intervention studies, this was necessary to prevent the assessments from being unreasonably long. For the present study, measures with more items would have been very beneficial. Coefficient alpha values for many measures, including the processes of change, pros, and cons were often low (but still within an acceptable range); internal consistency for each measure would be improved with additional items. Additional items for measures may have also improved the predictive power of constructs. Relations among processes of change and mediators, as well as processes of change and smoking outcomes, were typically smaller in magnitude than the relations among mediators and smoking outcomes. This finding may be partially explained by the two-item scales for the processes. Additional items for each of the processes could increase the magnitude of relations, and this could result in more evidence for statistical mediation.

Smoking outcome was an important component of all mediation models and was associated with some limitations. Unlike other constructs in the present study (e.g., Consciousness Raising, Cons of Smoking), which were previously validated in past studies, the smoking outcome was specifically developed to perform statistical mediation models for smoking. The two items that measured the latent variable for smoking outcome, time to first cigarette and cigarettes per day, have been used extremely often in smoking intervention studies, but are typically not combined as a latent variable. Thus, the measure could benefit from more vigorous psychometric testing in the future. As with the other scales, the smoking outcome would

be strengthened by additional items. One type of item that would be particularly beneficial for the smoking outcome would be an item that reflected stage progression. The present smoking outcome may not have fully captured subtle changes for participants in PC due to the content of the items (time to first cigarette, cigarettes per day). Someone in PC may not change on these overt behaviors, but may progress to C, which predicts future change (Blissmer et al., 2010). Regardless, the smoking outcome variable performed very well in the present study as well as in all single mediator models, and it correlated highly with Situational Temptations to Smoke, which has been used in the past as a smoking outcome variable (Velicer et al., 1996).

Fourth, timing issues related to both measurement and intervention were also limitations. At least three time points were necessary to run the longitudinal mediation models; baseline, 12 months, and 24 months were selected because all original five studies had full assessments at these time points. However, in all of these studies the intervention was complete by the 12-month time point. Thus, the most dramatic changes may have occurred between baseline and 12 months, but these could not be fully captured in the mediation models. The changes from 12 months to 24 months involved the lasting effects of the intervention. The mediation models in the present study described changes over a wide time frame, and they would be improved with additional time points.

All of these areas of limitations could be addressed with a study specifically designed to test mediational hypotheses. An ideal TTM-tailored intervention study to test mediation would (1) recruit a large, diverse sample; (2) collect data for all TTM constructs for both treatment and control groups; (3) utilize scales for TTM constructs that had more than two items each and include extra items to assess smoking behavior; and (4) perform full assessments (at least) every six months. With the data produced by such a study, the resulting mediation models would provide very compelling evidence of the mechanisms of smoking behavior change.

An important limitation of the present study, likely unrelated to the use of secondary data, involved the signs of the regression paths in the mediation models. In many instances, the signs of

regression paths were opposite from what was expected. The longitudinal regression paths in particular had some unusual patterns. Notably, the paths from the mediator at 12 months to the smoking outcome at 24 months (b_2) in the mediation pathways were consistently found to be negative. This unexpected finding suggests the presence of suppressor effects (Kline, 2005; MacKinnon, 2008; Velicer, 1978). Paths with unexpectedly negative signs were also found in the evaluation of the single mediator models and multiple mediator models (manuscripts 1, 2, 3, and 4 in the present series of studies). Suppressor effects are common in longitudinal structural equation models and are even more common when latent variables are involved (Maassen & Bakker, 2001).

The unexpectedly negative b_2 paths likely represent examples of negative suppression, where the signs are reversed due to the presence of other, stronger positive predictors of smoking outcome at 24 months. For example, consider the Pros of Smoking; for a b_2 path from the Pros of Smoking at 12 months to smoking at 24 months, the other, stronger predictors included smoking outcome at 12 months and the Pros of Smoking at 24 months. Further evidence of suppression was found through modification of the models. When one of the strong predictors of smoking outcome at 24 months was deleted from the model (either the smoking outcome at 12 months or the Pros of Smoking at 24 months), the sign of the longitudinal mediation path b_2 flipped from negative to positive. This suggested that b_2 was negative simply because of the other predictors. Due to suppression effects, the signs of regression paths need to be interpreted with caution. Instead, effect sizes should be the emphasis of interpretation. The magnitude of each regression path, as described by the standardized coefficients, is very important. The effect size of the overall mediation pathway, calculated from the product of the standardized coefficients, is also more important to describing mediation than the signs of any individual paths.

Future Directions for Analysis

An important validity check for the statistical mediation models developed in the present study will be whether the estimates are consistent across subsamples. For example, different age

groups may demonstrate different patterns. In the framework of SEM, multiple subsamples can be compared simultaneously with factorial invariance procedures (Meredith, 1993). A separate study (manuscript 6 in the present series of studies) will evaluate factorial invariance across a series of subgroup variables, including age, education level, gender, race, and original study.

Conclusions

The present study built statistical mediation models with multiple processes of change from the results of single mediator models. The development of models with multiple IVs helped further highlight mediating mechanisms that drove the observed changes in smoking behavior in the five TTM-based smoking interventions. For individuals beginning intervention in PC, Consciousness Raising, Dramatic Relief, Environmental Reevaluation, Social Liberation, and Self-Reevaluation were found to be essential strategies for driving decreases in smoking through influencing the Pros and Cons of Smoking. For participants in C, these five experiential processes, along with Counter Conditioning and Stimulus Control, were key for driving decreases in smoking through the Pros of Smoking and Situational Temptations. This insight into the mechanisms of smoking behavior change has the potential to lead to the improvement and refinement of smoking cessation interventions. Modern, computerized interventions can adapt to make intervention contacts as relevant as possible by tailoring to individuals to focus on which behavioral mechanisms are the most important. By focusing on the most important Processes of Change for Smoking, interventions have the empirical evidence-based potential to become more direct and effective.

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Table 5.1. Summary of models that demonstrated evidence of statistical mediation (abbreviations used in other tables are included in parentheses)

Independent Variable	Mediator	Product of Std. a1 and b2
Baseline Stage: Precontemplation		
Consciousness Raising (CR)	Pros of Smoking (Pros)	0.105
Dramatic Relief (DR)	Pros of Smoking (Pros)	0.060
Self-Reevaluation (SR)	Pros of Smoking (Pros)	0.081
Social Liberation (SO)	Pros of Smoking (Pros)	0.108
Environmental Reevaluation (ER)	Cons of Smoking (Cons)	0.045
Self-Reevaluation (SR)	Cons of Smoking (Cons)	0.089
Social Liberation (SO)	Cons of Smoking (Cons)	0.130
Helping Relationships (HR)	Cons of Smoking (Cons)	0.034
Self Liberation (SL)	Cons of Smoking (Cons)	0.040
Consciousness Raising (CR)	Situational Temptations (ST)	0.087
Dramatic Relief (DR)	Situational Temptations (ST)	0.034
Environmental Reevaluation (ER)	Situational Temptations (ST)	0.033
Baseline Stage: Contemplation		
Consciousness Raising (CR)	Pros of Smoking (Pros)	0.090
Dramatic Relief (DR)	Pros of Smoking (Pros)	0.074
Environmental Reevaluation (ER)	Pros of Smoking (Pros)	0.040
Self-Reevaluation (SR)	Pros of Smoking (Pros)	0.078
Social Liberation (SO)	Pros of Smoking (Pros)	0.062
Counter Conditioning (CC)	Pros of Smoking (Pros)	-0.111
Environmental Reevaluation (ER)	Cons of Smoking (Cons)	0.025
Self-Reevaluation (SR)	Cons of Smoking (Cons)	0.055
Social Liberation (SO)	Cons of Smoking (Cons)	0.063
Self-Reevaluation (SR)	Situational Temptations (ST)	0.084
Counter Conditioning (CC)	Situational Temptations (ST)	-0.053
Stimulus Control (SC)	Situational Temptations (ST)	-0.052
Baseline Stage: Preparation		
Self-Reevaluation (SR)	Situational Temptations (ST)	0.133

Table 5.2. Fit indices for multiple IV models, PC and C

Model	N	χ^2	(df)	NFI	CFI	RMSEA	(90% RMSEA)
Baseline Stage: Precontemplation							
CR & DR – Pros	1145	1007.917	(269)	0.952	0.988	0.017	(0.011, 0.021)
CR & SO – Pros	1145	608.100	(269)	0.972	1.000	0.000	-
CR & SR – Pros	1145	1109.131	(269)	0.948	0.982	0.021	(0.017, 0.025)
DR & SO – Pros	1145	450.330	(269)	0.996	1.000	0.000	-
DR & SR – Pros	1145	1447.713	(269)	0.941	0.970	0.029	(0.025, 0.032)
SR & SO – Pros	1145	532.384	(269)	0.992	1.000	0.000	-
ER & HR – Cons	1145	520.899	(269)	0.992	1.000	0.000	-
ER & SL – Cons	1145	660.803	(269)	0.986	1.000	0.000	-
ER & SO – Cons	1145	493.803	(269)	1.000	1.000	0.000	-
ER & SR – Cons	1145	840.086	(269)	0.979	1.000	0.000	-
SO & HR – Cons	1145	413.118	(269)	0.995	1.000	0.000	-
SO & SL – Cons	1145	498.552	(269)	0.993	1.000	0.000	-
SR & HR – Cons	1145	540.531	(269)	0.993	1.000	0.000	-
SR & SL – Cons	1145	805.438	(269)	0.975	1.000	0.000	-
SR & SO – Cons	1145	507.965	(269)	0.991	1.000	0.000	-
CR & DR – ST	1145	1218.412	(269)	0.958	0.984	0.022	(0.018, 0.026)
CR & ER – ST	1145	1147.291	(269)	0.972	0.997	0.010	(0.000, 0.016)
DR & ER – ST	1145	1149.798	(269)	0.971	0.995	0.014	(0.008, 0.019)
Baseline Stage: Contemplation							
CR & SR & CC – Pros	1243	1450.345	(423)	0.957	0.997	0.007	(0.000, 0.013)
CR & DR – Pros	1243	1062.832	(269)	0.956	0.987	0.018	(0.014, 0.022)
CR & ER – Pros	1243	858.280	(269)	0.970	0.997	0.009	(0.000, 0.015)
CR & SO – Pros	1243	843.128	(269)	0.965	1.000	0.000	(0.000, 0.010)
DR & CC – Pros	1243	700.711	(269)	0.986	1.000	0.000	-
DR & ER – Pros	1243	1013.601	(269)	0.969	0.994	0.014	(0.008, 0.019)
DR & SO – Pros	1243	589.014	(269)	0.985	1.000	0.000	-
DR & SR – Pros	1243	1376.024	(269)	0.935	0.961	0.034	(0.031, 0.037)
ER & CC – Pros	1243	656.541	(269)	0.990	1.000	0.000	-
ER & SO – Pros	1243	578.146	(269)	0.992	1.000	0.000	-
ER & SR – Pros	1243	792.358	(269)	0.978	1.000	0.000	(0.000, 0.005)
SL & CC – Pros	1243	999.131	(269)	0.967	0.999	0.004	(0.000, 0.012)
SR & SO – Pros	1243	706.284	(269)	0.976	1.000	0.000	-
ER & SO – Cons	1243	820.719	(269)	0.973	1.000	0.000	(0.000, 0.005)
ER & SR – Cons	1243	957.782	(269)	0.972	0.996	0.011	(0.003, 0.017)
SR & SO – Cons	1243	820.719	(269)	0.973	1.000	0.000	(0.000, 0.005)
CC & SC – ST	1243	1232.374	(269)	0.945	0.970	0.030	(0.027, 0.034)
SR & CC – ST	1243	835.339	(269)	0.973	0.997	0.009	(0.000, 0.015)
SR & SC – ST	1243	901.594	(269)	0.968	0.991	0.017	(0.013, 0.022)

- Lower confidence limit negative, interval not calculated

Table 5.3. Multiple IV models: unstandardized (with standard errors) and standardized longitudinal regression paths describing the mediation pathway; Processes of Change at baseline to mediator at 12 months ($a1_1$, $a2_1$, $a3_1$) and mediator at 12 months to smoking outcome at 24 months (b_2) – due to the large number of combinations tested, only models that demonstrated statistical significance for all paths ($a1_1$, $a2_1$, $a3_1$, b_2) are included

Model	**$a1_1$**	**s.e.**	**Std. $a1_1$**	**b_2**	**s.e.**	**Std. b_2**
	$a2_1$	**s.e.**	**Std. $a2_1$**	**$a3_1$**	**s.e.**	**Std. $a3_1$**
Baseline Stage: Precontemplation						
CR & SO – Pros	-0.301*	0.135	-0.199	-0.425*	0.106	-0.417
	-0.286*	0.130	-0.189			
DR & SO – Pros	-0.187*	0.092	-0.124	-0.428*	0.107	-0.415
	-0.343*	0.130	-0.227			
SR & SO – Pros	-0.226*	0.098	-0.149	-0.469*	0.113	-0.456
	-0.305*	0.127	-0.201			
ER & SO – Cons	-0.306*	0.127	-0.184	-0.174*	0.068	-0.212
	-0.641*	0.205	-0.385			
Baseline Stage: Contemplation						
CR & SR & CC – Pros	-0.777*	0.275	-0.252	-0.362*	0.103	-0.582
	-0.493*	0.204	-0.160	0.896*	0.282	0.291
DR & CC – Pros	-0.789*	0.231	-0.314	-0.373*	0.107	-0.494
	0.809*	0.267	0.322			
ER & CC – Pros	-0.367*	0.117	-0.159	-0.372*	0.097	-0.471
	0.685*	0.217	0.297			
SR & SO – Pros	-0.358*	0.126	-0.224	-0.365*	0.085	-0.349
	-0.213*	0.098	-0.133			
SR & SC – ST	-0.411*	0.106	-0.294	-0.465*	0.117	-0.304
	0.265*	0.078	0.190			

* $p < 0.05$

Table 5.4. Products, standard errors, 95% asymmetric confidence limits, and products of standardized longitudinal regression paths for the Processes of Change that demonstrated statistical significance for all paths ($a1_1$, $a2_1$, $a3_1$, b_2)

Model	Product of $a1_1$ and b_2	s.e.	(95% Product)	Product of Std. $a1_1$ and b_2
	Product of $a2_1$ and b_2	**s.e.**	**(95% Product)**	**Product of Std. $a2_1$ and b_2**
	Product of $a3_1$ and b_2	**s.e.**	**(95% Product)**	**Product of Std. $a3_1$ and b_2**
Baseline Stage: Precontemplation				
CR & SO – Pros	0.128	0.067	(0.014, 0.276)	0.083
	0.122	0.065	(0.012, 0.264)	0.079
DR & SO – Pros	0.080	0.045	(0.003, 0.179)	0.051
	0.147	0.068	(0.032, 0.297)	0.094
SR & SO – Pros	0.106	0.054	(0.014, 0.224)	0.068
	0.143	0.070	(0.023, 0.297)	0.092
ER & SO – Cons	0.053	0.032	(0.004, 0.126)	0.039
	0.112	0.058	(0.018, 0.243)	0.082
Baseline Stage: Contemplation				
CR & SR & CC – Pros	0.281	0.131	(0.065, 0.573)	0.147
	0.178	0.092	(0.027, 0.384)	0.093
	-0.324	0.141	(-0.637, -0.091)	-0.169
DR & CC – Pros	0.294	0.123	(0.089, 0.567)	0.155
	-0.302	0.135	(-0.603, -0.079)	-0.159
ER & CC – Pros	0.137	0.057	(0.040, 0.263)	0.075
	-0.255	0.107	(-0.491, -0.076)	-0.140
SR & SO – Pros	0.131	0.056	(0.035, 0.254)	0.078
	0.078	0.041	(0.007, 0.167)	0.046
SR & SC – ST	0.191	0.070	(0.072, 0.344)	0.089
	-0.123	0.049	(-0.230, -0.041)	-0.058

Figure 5.1. Autoregressive mediation model II template, with Processes of Change (P) as independent variables, mediating variables (M) as mediators, and smoking outcome (Smoking) as dependent variables; at the baseline, 12-month, and 24-month time points

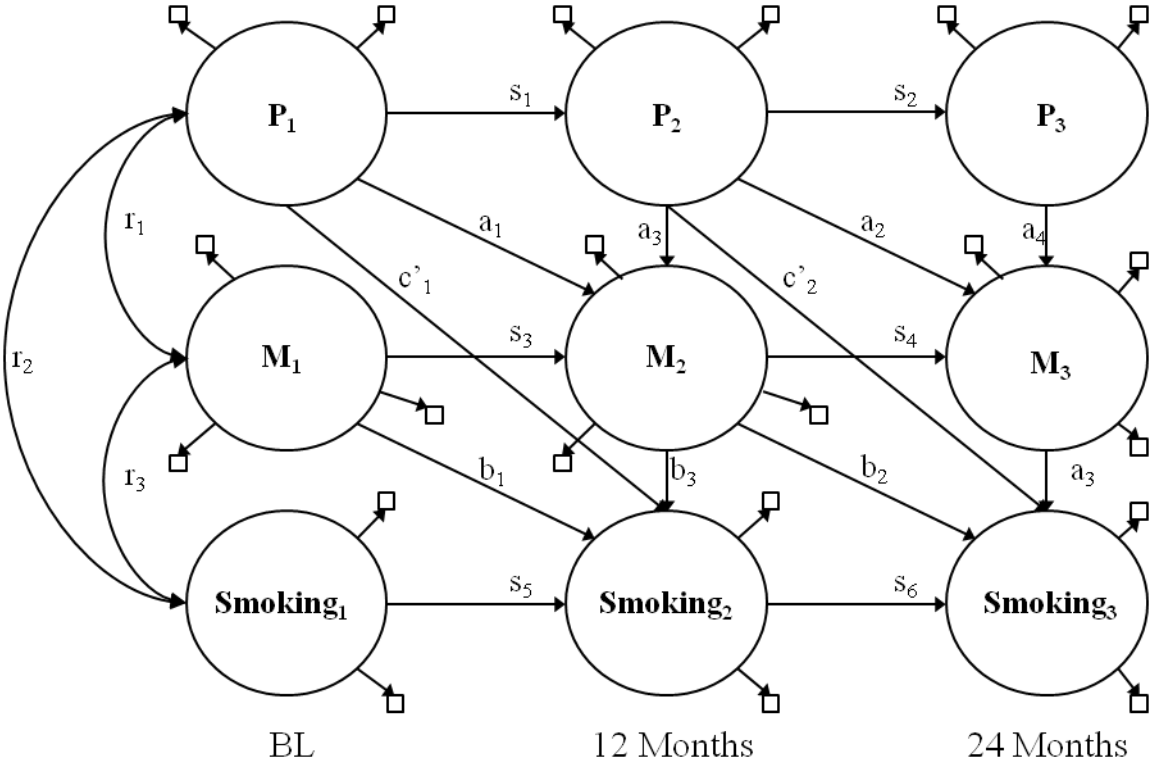


Figure 5.2. Autoregressive mediation model II template, modified to include multiple independent variables, with Processes of Change (P) as independent variables, mediating variables (M) as mediators, and smoking outcome (Smoking) as dependent variables; at the baseline, 12-month, and 24-month time points (item loadings, stability paths, and contemporaneous mediation paths not labeled to simplify diagram)

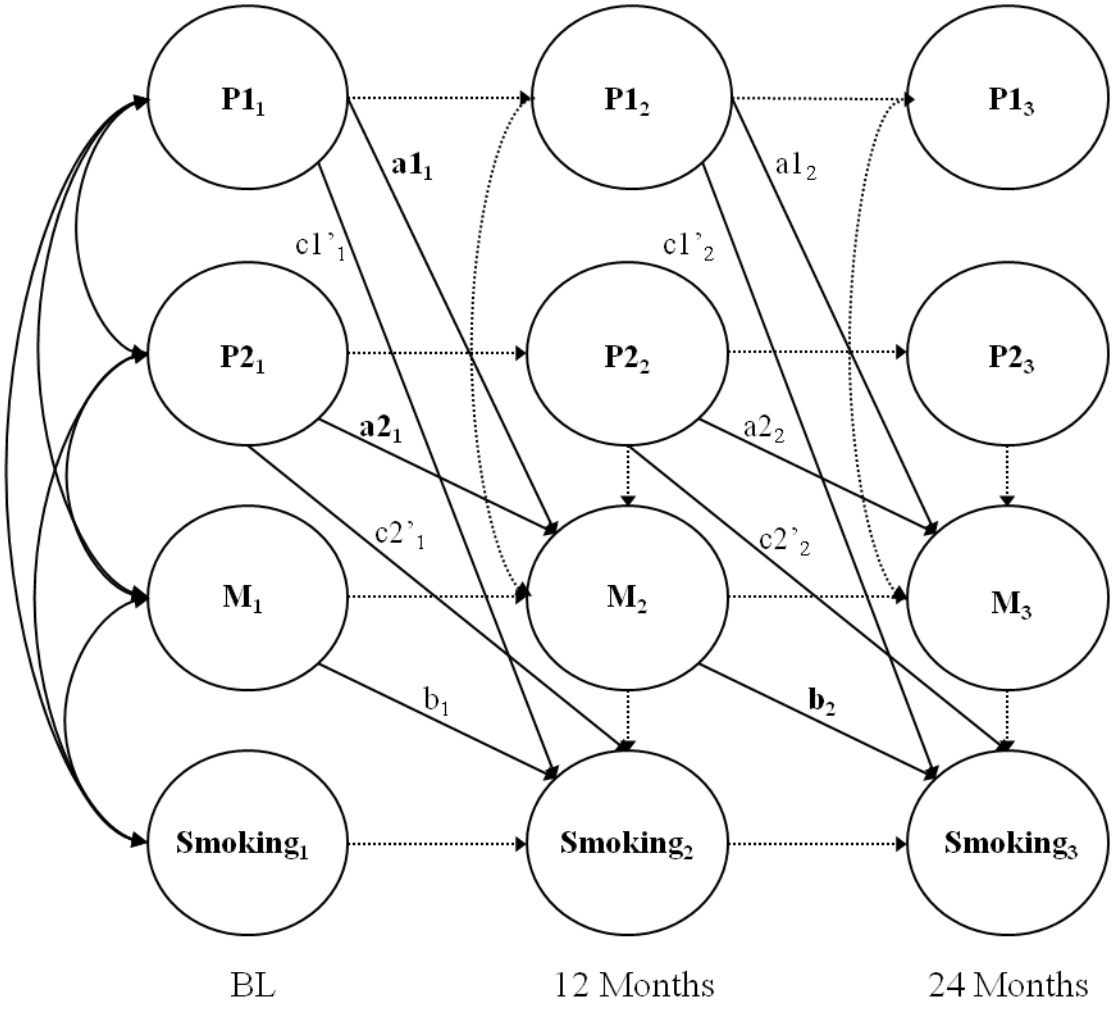
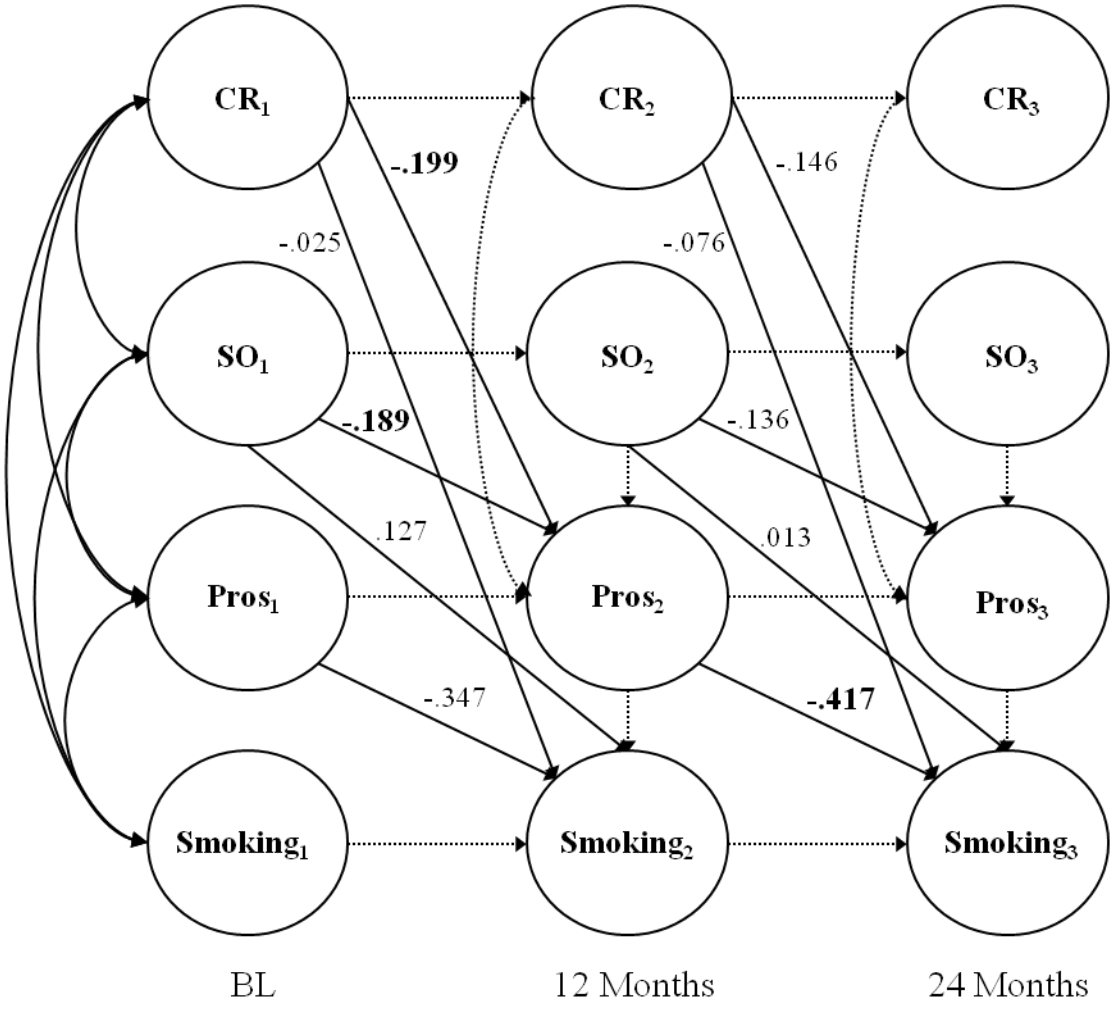


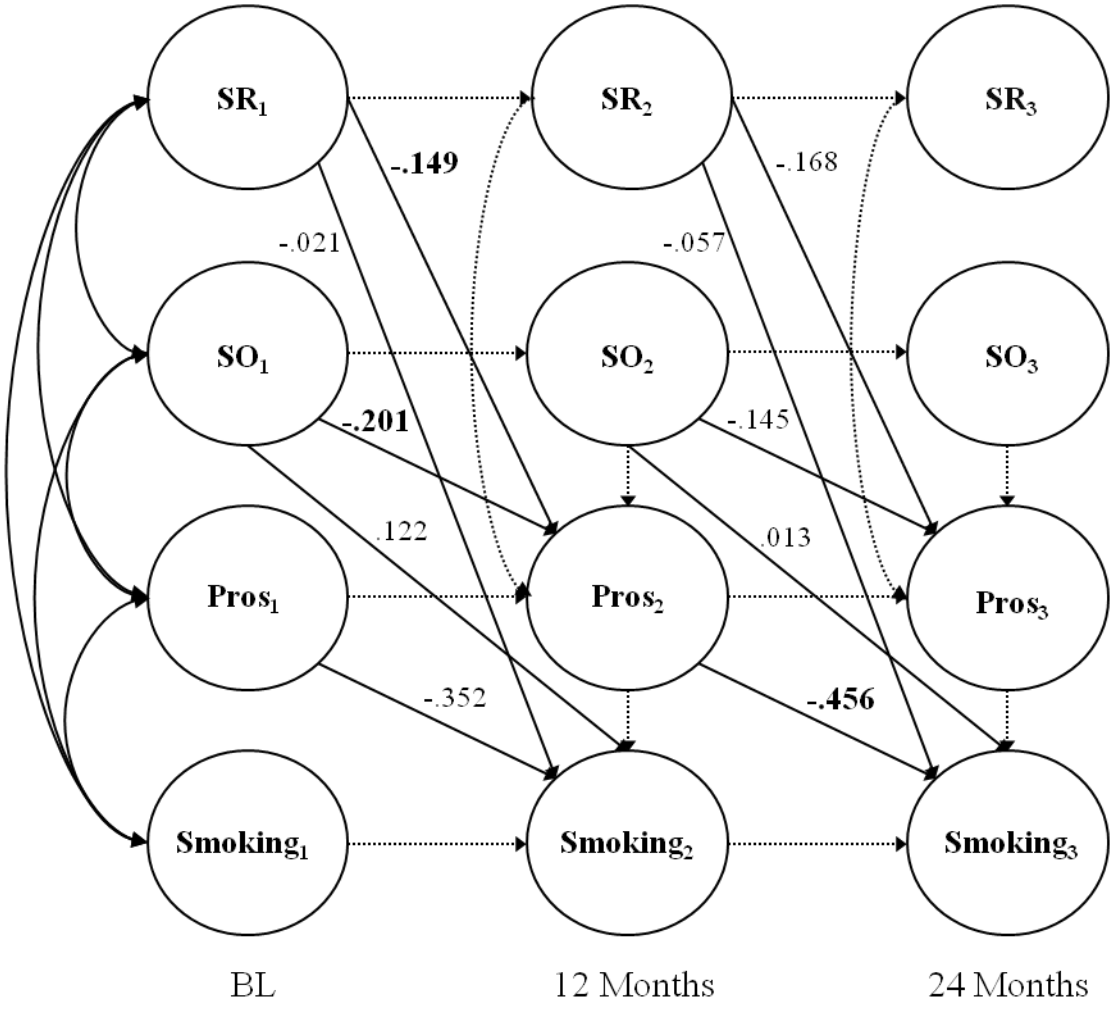
Figure 5.3. Multiple IV model at PC; with Consciousness Raising (CR) and Social Liberation (SO) as independent variables, Pros of Smoking (Pros) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



Product of standardized $a1_1$ and b_2 paths = .083

Product of standardized $a2_1$ and b_2 paths = .079

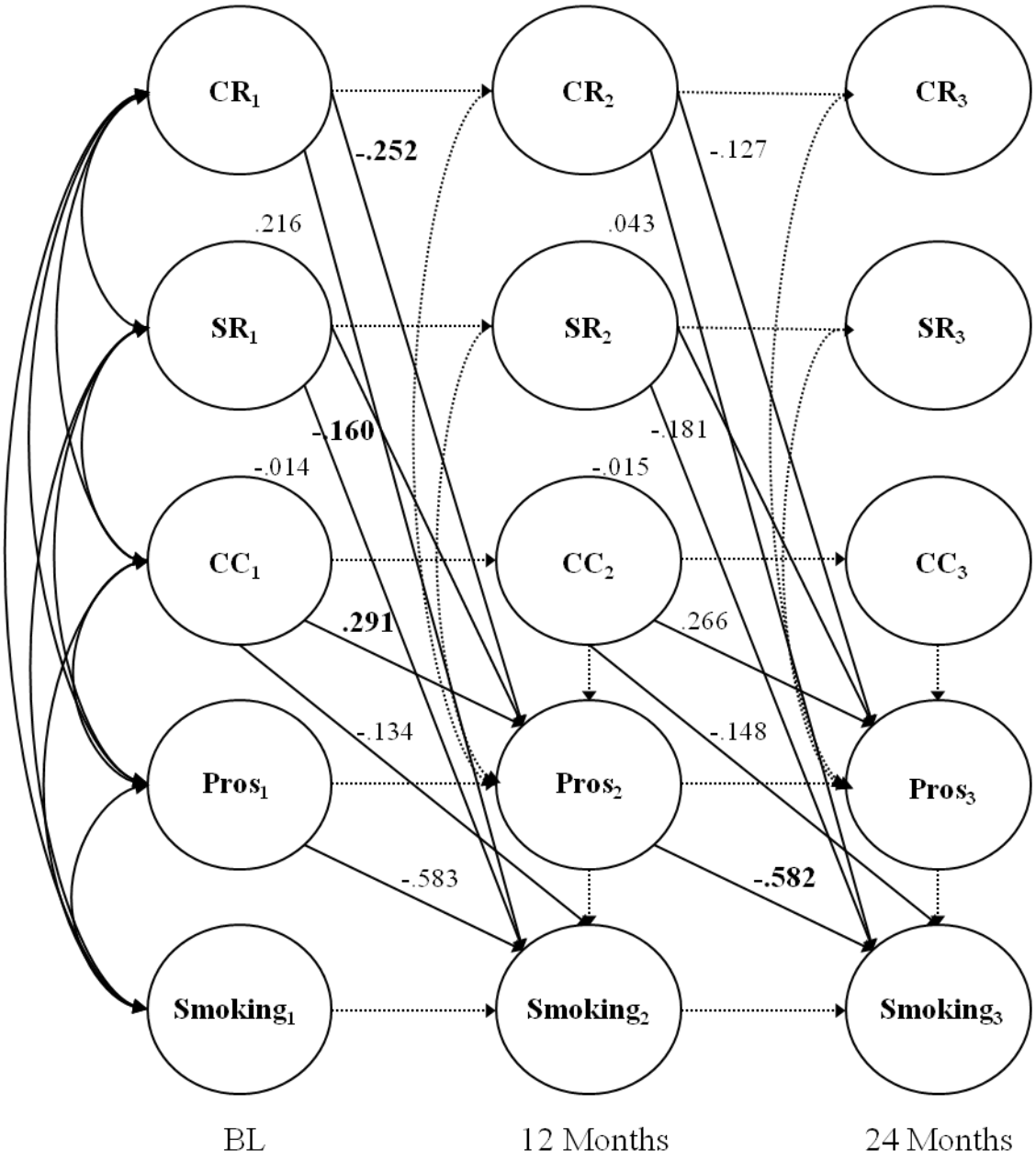
Figure 5.4. Multiple IV model at PC; with Self-Reevaluation (SR) and Social Liberation (SO) as independent variables, Pros of Smoking (Pros) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



Product of standardized $a1_1$ and b_2 paths = .068

Product of standardized $a2_1$ and b_2 paths = .092

Figure 5.5. Multiple IV model at C; with Consciousness Raising (CR), Self-Reevaluation (SR), and Counter Conditioning (CC) as independent variables, Cons of Smoking (Cons) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients

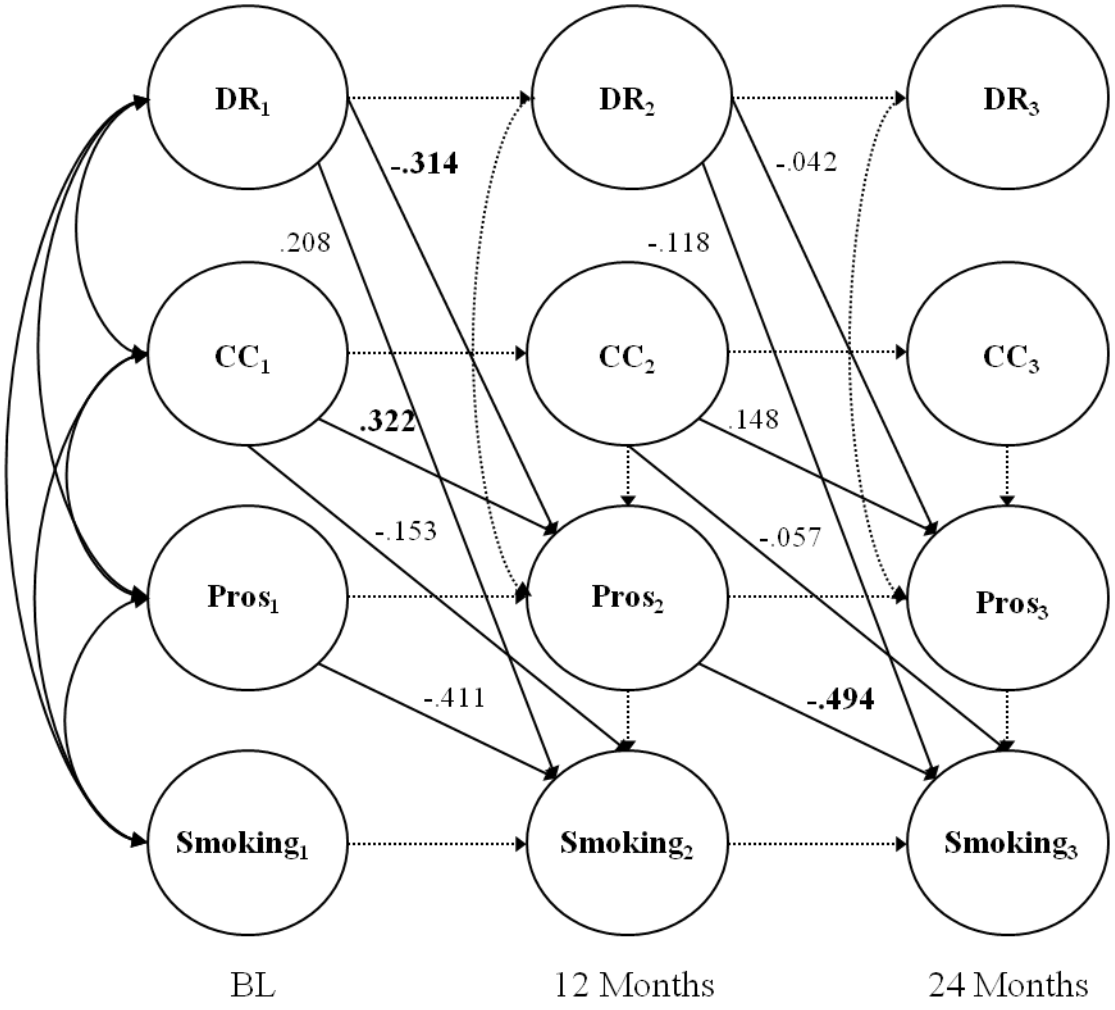


Product of standardized $a1_1$ and b_2 paths = .147

Product of standardized $a2_1$ and b_2 paths = .093

Product of standardized $a3_1$ and b_2 paths = -.169

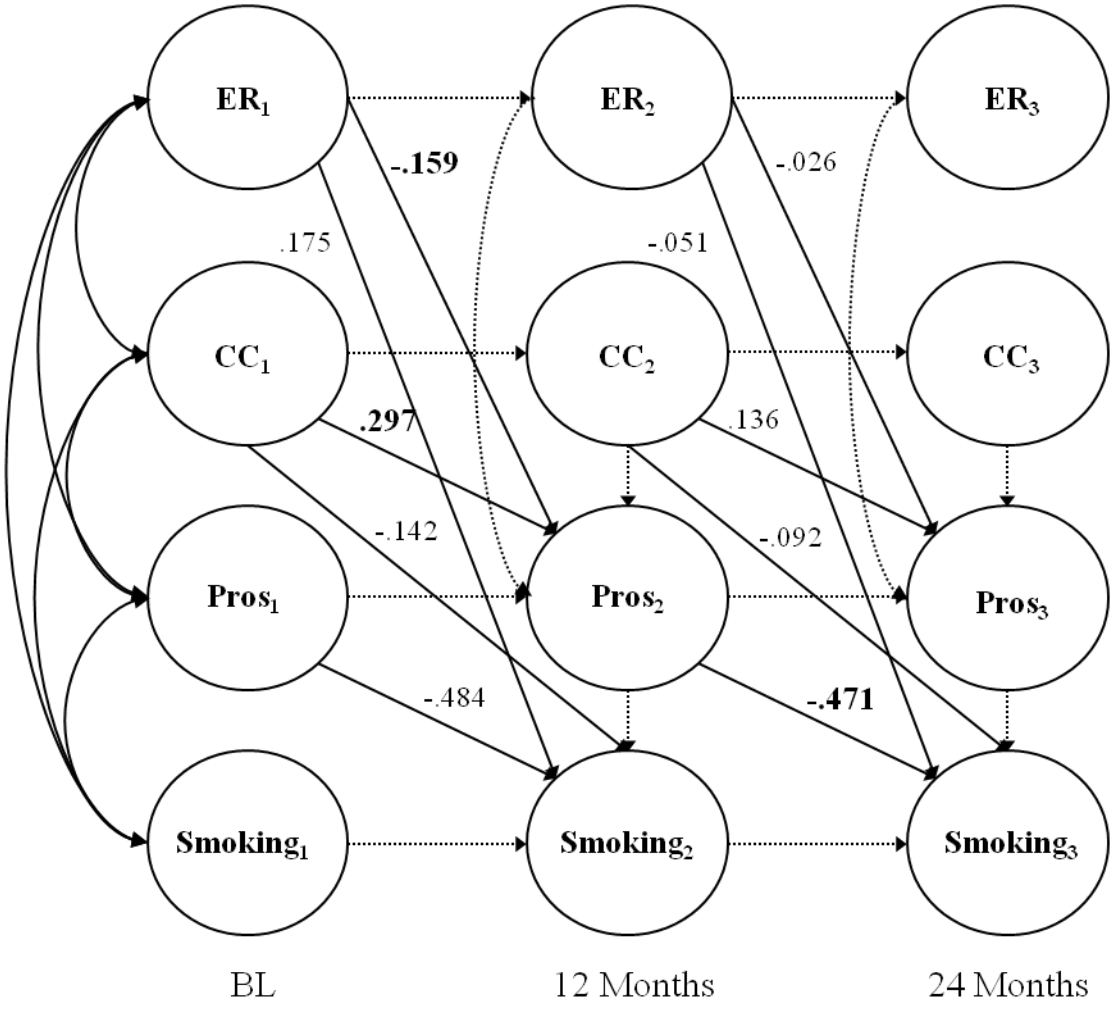
Figure 5.6. Multiple IV model at C; with Dramatic Relief (DR) and Counter Conditioning (CC) as independent variables, Pros of Smoking (Pros) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



Product of standardized $a1_1$ and b_2 paths = .155

Product of standardized $a2_1$ and b_2 paths = -.159

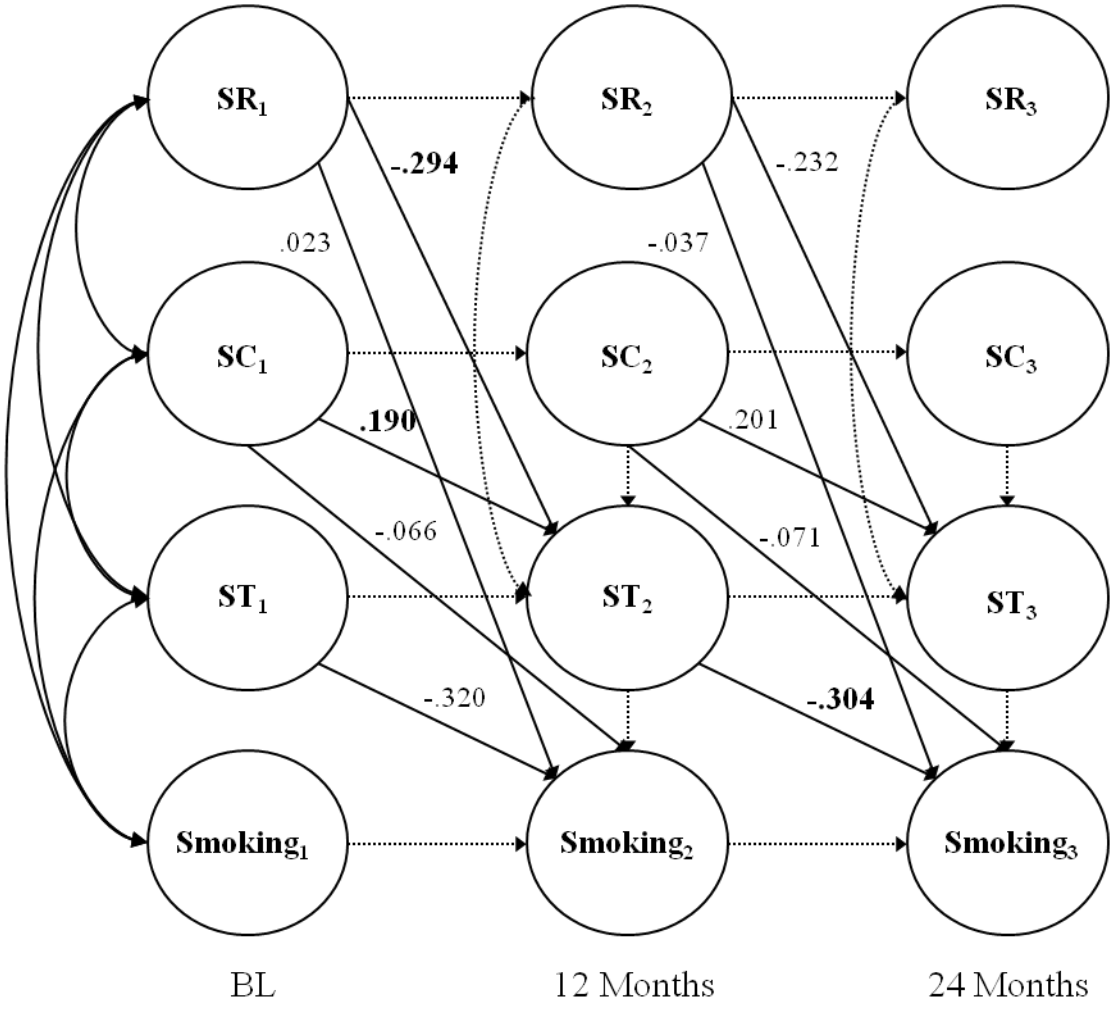
Figure 5.7. Multiple IV model at C; with Environmental Reevaluation (ER) and Counter Conditioning (CC) as independent variables, Pros of Smoking (Pros) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



Product of standardized $a1_1$ and b_2 paths = .075

Product of standardized $a2_1$ and b_2 paths = -.140

Figure 5.8. Multiple IV model at C; with Self-Reevaluation (SR) and Stimulus Control (SC) as independent variables, Situational Temptations (ST) as mediators, and smoking outcome (Smoking) as dependent variables, with standardized regression coefficients



Product of standardized $a1_1$ and b_2 paths = .089

Product of standardized $a2_1$ and b_2 paths = -.058

MANUSCRIPT 6

Testing for Moderation in Longitudinal Mediation Models of Smoking Behavior Change: Factorial Invariance Across Subgroups

Manuscript to be submitted to *Prevention Science*

Abstract

Investigating and quantifying the mechanisms that underlie behavior change is essential to understanding what drives effective interventions. The present study tested for the presence of statistical moderation in a series of 20 statistical mediation models that previously demonstrated evidence of statistical mediation. Moderator variables influence the direction or degree of association between an independent variable and a dependent variable. The present study utilized combined data from five randomized Transtheoretical Model (TTM)-tailored intervention studies for participants in Precontemplation (PC; N = 1145), Contemplation (C; N = 1243), and Preparation (PR; N = 499) stages at baseline. Statistical mediation models under investigation were autoregressive, three-wave models (baseline, 12 months, and 24 months) developed within each stage of change. The ten Processes of Change for Smoking were used as independent variables, Pros of Smoking, Cons of Smoking, and Situational Temptations to Smoke were used as mediators, and a behavioral smoking outcome was used as the dependent variable. Factorial invariance testing in SEM was employed to test for differences across subgroups associated with five variables: age, education level, gender, race, and original study. The highest level of invariance, Strict Factorial Invariance, which required factor loadings, measurement errors, regression paths, and covariances to be equivalent across subgroups, was a good fit or better (CFI > 0.95, RMSEA < 0.05) across all variables for all mediation models. The absence of evidence for moderation suggests that these models describe mediating mechanisms that are robust across demographic and study-related variables. These models highlight combinations of strategies for changing behavior that are most related to smoking outcomes. Assessing the mechanisms of behavior change is crucial to enhancing basic knowledge and informing intervention efforts.

Keywords: Statistical Mediation Analysis, Factorial Invariance, Smoking Cessation, Transtheoretical Model, Processes of Change

Testing for Moderation in Longitudinal Mediation Models of Smoking Behavior Change: Factorial Invariance Across Subgroups

Mechanisms of behavior change explain how and why behavior change occurs. Better understanding behavioral mechanisms necessitates better understanding variables that account for observed changes in behavior. Despite the importance of mechanisms of behavior change, knowledge about these mechanisms is presently very limited (NIH, 2009; 2012). Investigating and quantifying such mechanisms that underlie behavior change is essential to understanding what drives effective interventions, and many content areas would greatly benefit from a comprehensive investigation of the mechanisms that drive behavior change.

Cigarette smoking represents a key health behavior that needs to be better understood. Despite decades of prevention and intervention efforts, smoking remains a critical concern for public health in the United States. Approximately 19% of U.S. adults are smokers, and while smoking prevalence rates have decreased from approximately 42% in 1965, this decrease seems to be slowing (Centers for Disease Control [CDC], 2011a; 2011b; 2012). An estimated 443,000 adults die from smoking-related illnesses every year, and smoking is estimated to cost the United States $96 billion and $97 billion in direct medical expenses and lost productivity, respectively (CDC, 2008; 2012). Given the extreme health and economic costs of smoking, improving interventions to help smokers quit is of paramount importance. Over two-thirds of smokers report that they want to quit smoking (CDC, 2011c). Better understanding the behavioral mechanisms that help smokers change their behavior will emphasize behavioral strategies to aid quitting smoking and address a major health concern.

The present study built upon results from a series of statistical mediation analyses, which were performed on data from five effective smoking cessation intervention studies, based on the Transtheoretical Model (TTM), to test for moderator variables. Investigating moderation in

statistical mediation analysis is an important step involved in quantifying mechanisms of behavior change.

Statistical Mediation Analysis and Moderation

In general, mediation models are utilized to investigate how and why two things are related. Intermediate variables that come between independent variables and dependent variables are known as mediating variables, or mediators. A mediator acts as a third variable and represents the mechanism through which an independent variable influences an outcome (Baron & Kenny, 1986). The most basic model (MacKinnon, 2008) involves three key variables: an independent variable, X, a mediating variable, M, and a dependent variable, Y. From this simple model, additional independent variables, mediating variables, time points, and other components can be added to develop increasingly complex mediation models.

In addition to investigating mediators, statistical mediation analysis typically involves moderators. Moderator variables influence the direction or degree of association between an independent variable and a dependent variable (Baron & Kenny, 1986; MacKinnon, 2008). The effects of moderators are synonymous with interaction effects. One method to test for moderators is to split a dataset into multiple subgroups and compare statistical mediation models across these subgroups. Often demographic variables, such as age, gender, and education level are evaluated as potential moderators. Investigating the degree to which mediation models are influenced by such subgroups is crucial to the validity of the statistical mediation analyses and valuable to understanding the consistency and generalizability of the mediation models. In the framework of an intervention designed to change behavior, mediators are the mechanisms of behavior change. Thus, testing for moderators is a crucial component of understanding how variables drive behavior change in interventions.

The Transtheoretical Model of Behavior Change

All models were developed with secondary data from TTM-tailored smoking interventions. The TTM is an integrative framework that consists of multiple dimensions that

assess different components of behavior change (Prochaska & Velicer, 1997; Velicer, Prochaska, Fava, Rossi, Redding, Laforge, & Robbins, 2000). Essentially, the TTM represents a model of how individuals adopt healthy behaviors and discontinue unhealthy ones (Brewer & Rimer, 2008). The core constructs of the TTM include stages of change, processes of change, decisional balance, and self-efficacy. Tailored interventions based on the TTM have been empirically validated and have demonstrated effectiveness for a wide variety of behaviors, including smoking (Krebs, Prochaska, & Rossi, 2010; Noar, Benac, & Harris, 2007; Velicer, Prochaska, & Redding, 2006b; Velicer, Redding, Sun, & Prochaska, 2007b).

Smoking research and the TTM have a very extensive history. Multiple components of the TTM were empirically refined with smoking as the content area, including stage of change (DiClemente et al., 1991), processes of change (Prochaska & DiClemente, 1983; Prochaska, Velicer, DiClemente, & Fava, 1988), decisional balance (Velicer, DiClemente, Prochaska & Brandenberg, 1985), and self-efficacy (Velicer, DiClemente, Rossi, & Prochaska, 1990), with longitudinal studies supporting predictive validity in some randomized and some nonrandomized studies (DiClemente et al., 1991; Prochaska, Velicer, Fava, Rossi, & Tsoh, 2001; Prochaska et al., 2004, 2005; Redding et al., 2011; Sun, Prochaska, Velicer, & LaForge, 2007; Velicer et al., 2006b, 2007b). The TTM has been applied to a wide variety of behaviors (e.g., alcohol use, exercise, diet, UV protection, mammography screening), but it has been most widely applied to smoking (Krebs et al., 2010; Noar et al., 2007).

Overview of Current Study

This is the sixth of a series of six studies that utilized mediation analysis to better understand mechanisms of smoking behavior change in TTM-based studies. The first three studies focused on the development of single mediator models to investigate smokers within the three pre-action stages of smoking: Precontemplation (PC), Contemplation (C), and Preparation (PR). The fourth and fifth studies involved building on and refining the results of the single mediator models through the development of multiple mediator models and multiple independent

variable (IV) models. All models were longitudinal, and the analytical framework was guided by the TTM, with the ten processes of change acting as independent variables, pros, cons, and self-efficacy acting as mediators, and a smoking behavior outcome acting as the dependent variable. A summary of the final models that resulted from these series of analyses is included in Table 6.1.

The goal of the present study was to test for moderation by comparing statistical mediation models across subgroups. Moderation was evaluated across five subgroup variables, including individual studies within the combined datasets and demographic subgroups (age, gender, race, and education level). The individual studies within the combined data set were hypothesized not to act as moderators, as all studies involved the same TTM-tailored smoking cessation intervention. Demographic subgroups were also hypothesized not to act as moderators because the interventions were explicitly designed to be population-based. Ultimately, these multiple-group models will assess the validity and generalizability of statistical mediation relations and evaluate the degree to which the mechanisms of behavior change for smoking are moderated by the characteristics of the sample.

Method

Participants

Data from five different smoking intervention studies were combined in the present study. Combining data from multiple large studies was a necessary step to create a sample size large enough to split into subgroups and analyze the complex statistical mediation models. These studies could be combined because of a number of crucial similarities. All five studies were large, randomized, clinical trials that were successful in decreasing smoking rates. Each study collected longitudinal data, used representative, population-based sampling, and assessed all key TTM constructs (with the same items) necessary to run the mediation analyses. Only participants that received the same TTM-based smoking intervention were included in the combined sample; participants in control conditions or in other treatment groups were not included. Separate combined data sets were created to examine mediation models for participants in the three pre-

action stages (PC, C, and PR) at baseline. Statistical mediation models were developed within separate stages, rather than combining individuals across stages, because differences in stage have demonstrated nonlinear relations with the other TTM variables (Velicer, Prochaska, Rossi, & DiClemente, 1996). The five separate studies that make up the combined sample were labeled Parent, Patient, Worksite, RDD, and Health; sample sizes for each are included in Table 6.2.

Original Studies. The Parent study (Prochaska et al., 2004) involved parents of students recruited for a school-based study (N at PC=153; C =145; PR = 50). In addition to a smoking intervention, participants in this study who were at risk also received interventions on diet and sun exposure. The Patient study (Prochaska et al., 2005) involved patients from an insurance provider list (N at PC=177; C =287; PR = 136). In addition to a smoking intervention, participants in this study who were at risk also received interventions on diet, sun exposure, and mammography. The Worksite study (Velicer et al., 2004) involved employees from a sample of worksites (N at PC=77; C =80; PR = 28). In addition to a smoking intervention, participants in this study who were at risk also received interventions on diet, sun exposure, and exercise. The RDD study (Prochaska et al., 2001) involved participants from a random digit dial (RDD) sample (N at PC=565; C =565; PR = 228). This study intervened only on smoking. The Health study (Velicer, Friedman, Redding, Migneault, & Hoeppner, 2006a; Velicer, Friedman, Redding, Migneault, Hoeppner, & Prochaska, 2007a) involved participants who were smokers and who were at risk for diet and exercise in a multiple risk behavior study (N at PC=173; C =166; PR = 57). In addition to a smoking intervention, participants in this study also received interventions on diet and exercise.

Total Combined Samples. The three combined samples included participants in PC at baseline (N = 1145), participants in C at baseline (N = 1243), and participants in PR at baseline (N = 499). Details for demographics related to subgroups tested for mediation are included in Table 6.2.

Intervention

All participants received a TTM-tailored smoking intervention that assessed key variables at baseline, 12 months, and 24 months. The smoking intervention was a tailored, expert system intervention, where participants received feedback matched to how they responded to TTM constructs. All interventions began with an assessment of basic demographic variables, smoking variables, and the core measures from the TTM. Interventions provided stage-matched and tailored feedback in a series of three reports at baseline, 3 months, and 6 months (RDD) or at baseline, 6 months, and 12 months (Parent, Patient, Worksite, and Health). Tailoring in these feedback reports involved both highlighting certain strategies to change (processes of change) as well as normative and ipsative comparisons. Data from studies with different intervention schedules were combined because these two different schedules did not produce different results (Velicer et al., 2007b). Participants in all interventions also received multiple follow-up assessments. Additional details involving the expert system intervention are available elsewhere (Velicer & Prochaska, 1999; Velicer et al., 1993).

Measures

Analyses performed in the present study involved all core TTM constructs, including stage of change, processes of change, decisional balance, and self-efficacy. Additional variables, related to smoking behavior, were also used to measure a latent variable for smoking outcome.

Stage of Change. The stages of change represent the temporal dimension of TTM. The stages act as the central organizing framework of the model. Varying levels of readiness to change are represented by five stages: Precontemplation (PC), Contemplation (C), Preparation (PR), Action (A), and Maintenance (M) (DiClemente et al., 1991; Prochaska & DiClemente, 1983). Stages of change for smoking were assessed with algorithms developed to assess intentions to quit smoking (Prochaska & DiClemente, 1983). The PC stage includes participants that report being smokers and report not intending to quit in the next six months. The C stage includes participants that report being smokers and report intending to quit in the next six months. The C stage also includes participants that reported intending to quit in the next month but did not

have a successful 24-hour quit attempt in the past year. The PR stage includes participants that report being smokers, report intending to quit in the next month, and report having at least one successful 24-hour quit attempt in the past year.

Processes of Change. The processes of change represent the independent variable dimension of the TTM. The processes involve strategies for changing one's behavior; in TTM-based interventions, the processes play a critical role in tailoring the intervention to the individual. There are ten Processes of Change for Smoking (Prochaska et al., 1988). The ten processes include experiential processes, which are cognitive and emotional strategies to change behavior, and behavioral processes, which represent more overt changes in behavior. The experiential processes include Consciousness Raising, Dramatic Relief, Environmental Reevaluation, Self-Reevaluation, and Social Liberation. The behavioral processes include Counter Conditioning, Helping Relationships, Reinforcement Management, Self Liberation, and Stimulus Control. Detailed descriptions of the Processes of Change for Smoking are available elsewhere (Prochaska et al., 1988). Participants were asked to rate how often they used each process in the last month on a 5-point Likert scale ranging from 1 (Never) to 5 (Repeatedly). Each of the processes was a latent variable measured by two items; details for the items are included in Appendix A. In the total sample, coefficient alphas for the Processes of Change for Smoking scales ranged from 0.60 to 0.84.

Decisional Balance. The decisional balance construct represents part of the intermediate variable dimension of the TTM. Decisional balance, originally adapted from Janis and Mann (1977), assess an individual's weighing of the pros and cons of engaging in a behavior. The relationship between decisional balance and the stages of change has been replicated across more than 48 different health behaviors (Hall & Rossi, 2008). The Decisional Balance Scale for Smoking is a six-item scale with three items for the Pros of Smoking and three items for the Cons of Smoking (Velicer et al., 1985). These items assess the relative importance of the pros and cons of smoking. Participants were asked to rate the importance of each item on a 5-point Likert scale

ranging from 1 (Not important) to 5 (Extremely important). The Pros of Smoking and the Cons of Smoking were represented by latent variables, each measured by three items; details for the items are included in Appendix A. In the total sample, coefficient alpha was 0.70 for the Pros of Smoking and 0.66 for the Cons of Smoking.

Self-Efficacy. The self-efficacy construct represents the other part of the intermediate variable dimension of the TTM. Originally adapted from Bandura (1977), the self-efficacy construct assesses an individual's perceived ability to perform behaviors in difficult situations. Self-efficacy increases as one transitions TTM stages (Velicer et al., 1990). Improved self-efficacy predicts improved outcomes; this relationship has been repeatedly demonstrated for smoking (Blissmer et al., 2010; Prochaska, DiClemente, Velicer, Ginpil, & Norcross, 1985; Prochaska, Velicer, DiClemente, Guadagnoli, & Rossi, 1991). In the framework of the TTM, self-efficacy either describes the confidence to engage in a healthy behavior or describes temptations to engage in an unhealthy behavior. For smoking, self-efficacy is measured by the Situational Temptations to Smoke scale (Velicer et al., 1990). The Situational Temptations describe situations that may lead some people to smoke. The instrument is a nine-item scale with three items for positive affect / social situations, three items for negative affect situations, and three items for habitual / craving situations. Participants were asked to rate how tempted to smoke they felt on a 5-point Likert scale ranging from 1 (Not at all tempted) to 5 (Extremely tempted). Details for the items are included in Appendix A. In the present study, averages of these three item content areas (e.g., positive affect / social situations) were calculated to represent Situational Temptations for Smoking with three items; a latent variable for Situational Temptations was measured by these three items. Coefficient alpha for this three-item scale was 0.78 in the total sample.

Smoking Outcome. The smoking behavioral outcome was a latent variable measured by two key items from the widely-used Fagerstrom Test for Nicotine Dependence (FTND; Fagerstrom, 1978), time to first cigarette and number of cigarettes smoked per day. These two

continuous variables were converted to 5-point scales, with higher values indicating more smoking. Details for the items are included in Appendix A. Coefficient alpha for this measure was 0.75 in the total sample.

Statistical Mediation Models

Moderator analyses were based on results from previous studies that developed statistical mediation models to investigate the mechanisms of smoking behavior change. These models shared a number of similarities. All models were longitudinal, utilizing data from assessments at three time points (baseline, 12 months, and 24 months), and all models included at least one of the Processes of Change (independent variables), at least one of the mediators (Pros, Cons, Situational Temptations), and the smoking outcome (dependent variable). Due to the complexity of these models, SEM was utilized to analyze the covariance structure, estimate regression paths, estimate error terms, and assess model fit. Models were developed with framework of the autoregressive mediation model II (Figure 6.1; Cole & Maxwell, 2003; Gallob & Reichardt, 1991, MacKinnon, 2008), with multiple mediator and multiple IV models extending this template. Missing data were estimated with maximum likelihood (ML) procedures to reduce bias associated with listwise or pairwise deletion (Allison, 2003; Enders & Bandalos, 2001). Statistical mediation was assessed in two steps. First, model fit was assessed to ensure that the statistical mediation model provided a valid framework to demonstrate mediation. Second, statistical mediation was assessed by evaluating mediation pathways. In three-wave autoregressive mediation models, regression paths from X at time 1 to M at time 2 (path a_1) and M at time 2 to Y at time 3 (path b_2) make up the mediation pathway, which is also known as the indirect effect or the intervening effect (MacKinnon, Lockwood, & Williams, 2004; Preacher & Hayes, 2008; Sobel, 1982). Mediation models with multiple independent variables or multiple dependent variables have multiple mediation pathways. Statistical significance of each of these paths was assessed separately in SEM; if each path demonstrated statistical significance, this finding suggested that this pathway was significant. To further assess for evidence of mediation,

asymmetric confidence intervals for the product of these paths were calculated (MacKinnon, 2008; Tofighi & MacKinnon, 2011). To show evidence of statistical mediation, these confidence intervals could not include zero.

Among the total of 90 (3 pre-action stages * 10 processes of change) single mediator models, there were 25 single mediator models that demonstrated empirical evidence of statistical mediation. These single mediator models were combined to create models with multiple mediators and models with multiple processes of change. These analyses produced a set of 20 models that demonstrated evidence of statistical mediation and could not be combined any further (see Table 6.1). These final models included three multiple mediator models at PC, four multiple IV models at PC, three single mediator models at PC, five multiple mediator models at C, three single mediator models at C, and one single mediator model at PR.

Statistical Moderation Analysis with Factorial Invariance

The 20 final mediation models were assessed for moderation by testing across subgroups. There were five subgrouping variables: study, age, gender, race, and education level. For each subgrouping variable, models for each subgroup were estimated and compared simultaneously; multiple-sample SEM was used to test for factorial invariance of the mediation models. A model is called *factorially invariant* when the model is the same for different subgroups of a population. Testing for factorial invariance is often performed in the context of testing psychometric assumptions for measures (Babbin et al., 2011; Harrington et al., 2011; McGee et al., 2012; Meredith, 1993; Ward, Velicer, Rossi, Fava, & Prochaska, 2004); it can also be utilized to test for moderation because the procedure identifies subgroups that do not fit a specified model. Four levels of factorial invariance, from the least restrictive to most restrictive, were assessed. The weakest level was Configural Invariance, which required the model specification to be the same across subgroups (zero loadings on the same constructs and unconstrained nonzero factor loadings). Second was Pattern Identity Invariance, which required the factor loadings to be equal across subgroups. Third, Strong Factorial Invariance required factor loadings and error terms to

be equivalent across subgroups. Fourth, Strict Factorial Invariance required factor loadings, error terms, regression paths, and covariances to be equivalent across subgroups. Mean structures were not estimated or tested for any of these levels of invariance.

To test for factorial invariance, separate subgroups needed to be created from the datasets at PC, C, and C. In general, when continuous variables were divided into categories (e.g., age, education), the goal was to avoid subgroup sizes of <100 to avoid convergence issues (Velicer & Fava, 1998). For other variables, subgroups that were too small for analysis had to eliminated. For age, samples were split into four age ranges (18-34, 35-44, 45-54, and ≥ 55). For education level, samples were split into three subgroups based on years of completed education (high school or less, ≤ 12; some college, 13-15; and four-year college or more, ≥ 16). For gender, samples were split into two subgroups (male and female). For race, samples were split into two subgroups (white and non-white). Demographic questions included a wide range of racial identities (black or African American; American Indian or Alaskan Native; Asian or Pacific Islander; other), but none of these subgroups were adequate for invariance testing. As a result, they had to be combined. Similarly, sample sizes were inadequate for individuals that identified as Hispanic. For study, samples were split into five subgroups (Health, Patient, Parent, RDD, and Worksite). Sample sizes for all subgroups, as well as sample sizes for each TTM stage of change, are summarized in Table 6.2.

To test for factorial invariance, SEM was employed using EQS 6.1 software (Bentler, 2007). All 20 statistical mediation models (Table 6.1) demonstrated a very good model fit. Model fit across subgroups was used to test for the presence of moderation. Good model fit provided evidence that models were robust across different subgroups, and that relations were not impacted by moderators. Poor fit provided evidence that the subgrouping variable was a moderator. The following indices were used as benchmarks to assess the model fit: likelihood ratio chi-square ($\chi 2$), Normed Fit Index (NFI), Comparative Fit Index (CFI), and Root Mean Squared Error of Approximation (RMSEA). Likelihood ratio chi-square provides a test for fit of the model based

on the chi-squared distribution. The chi-square test is extremely sensitive to large sample sizes (Kline, 2005) and will always reject models with large sample sizes. Due to this issue, and the large sample sizes in the present study, chi-square values are reported but results for its associated significance test are not. For NFI and CFI, values greater than 0.90 indicate good fit and values greater than 0.95 indicate very good fit (Bentler & Bonnet, 1980; Kline, 2005). For RMSEA, values less than 0.10 indicate good fit and values less than 0.05 indicate very good fit (Browne & Cudeck, 1993). Additionally, the difference in CFI between the model and the previous (lower) level of invariance (ΔCFI) was considered: a value of -0.01 or less indicates that the null hypothesis of invariance should not be rejected and that the model demonstrates invariance (Cheung & Rensvold, 2002). All models employed ML for missing data estimation.

Results

Factorial Invariance

The combination of 20 statistical mediation models (Table 6.1) across four levels of invariance (Configural Invariance, Pattern Identity Invariance, Strong Factorial Invariance, and Strict Factorial Invariance) for each of the five subgroup variables (see Table 6.2) produced an initial total of 400 separate models. Among the statistical mediation models, nine models had convergence errors associated with levels of the study subgrouping variable. In all cases, this was due to insufficient sample sizes. A pair of additional models was created for these nine cases, resulting in an additional 72 models for a grand total of 472 models. Strict Factorial Invariance was consistently found to hold across subgroups; no constraints were dropped in any of the models to achieve a better fit. Due to the volume of models, and the consistent findings, results of invariance tests are only reported at the level of Strict Factorial Invariance. Testing the difference in CFI (ΔCFI) was unnecessary due to exceptional fit statistics.

Factorial Invariance for Multiple Mediator Models at PC. Sample size was adequate across all subgrouping variables except for study. Models for the Worksite study (n = 77) could not converge. For the three multiple mediator models at PC, invariance for study was assessed

through two modifications of the study variable: study with Worksite removed (Study, 4 subgroups) and study with Worksite combined with the Parent study (combined n = 153 + 77 = 230; Study, combined). For all models and all variables, Strict Factorial Invariance held across the subgroups with a good fit or better (NFI > 0.90, CFI > 0.95, RMSEA < 0.05; see Table 6.3).

Factorial Invariance for Multiple IV Models at PC. Sample size was adequate across all subgrouping variables except for study. Models for the Worksite study (n = 77) could not converge. For the four multiple IV models at PC, invariance for stage was assessed through two modifications of the study variable (Study, 4 subgroups and Study, combined). For all models and all variables, Strict Factorial Invariance held across the subgroups with a very good fit (NFI > 0.95, CFI > 0.95, RMSEA < 0.05; see Table 6.4).

Factorial Invariance for Single Mediator Models at PC. Sample size was adequate across all subgrouping variables. For all models and all variables, Strict Factorial Invariance held across the subgroups with a very good fit (NFI > 0.95, CFI > 0.95, RMSEA < 0.05; see Table 6.5).

Factorial Invariance for Multiple IV Models at C. Sample size was adequate across all subgrouping variables except for study. Models for the Worksite study (n = 80) could not converge for the model with three processes (CR & SR & CC – Pros). For this one model, invariance for stage was assessed through two modifications of the study variable: study with Worksite removed (Study, 4 subgroups) and study with Worksite combined with the Parent study (combined n = 145 + 80 = 225; Study, combined). For all models and all variables, Strict Factorial Invariance held across the subgroups with a very good fit (NFI > 0.95, CFI > 0.95, RMSEA < 0.05; see Table 6.6).

Factorial Invariance for Single Mediator Models at C. Sample size was adequate across all subgrouping variables. For all models and all variables, Strict Factorial Invariance held across the subgroups with a very good fit (NFI > 0.095, CFI > 0.095, RMSEA < 0.05; see Table 6.7).

Factorial Invariance for Single Mediator Models at PR. Sample size was adequate across age, education, and gender. For race, models for non-white (n = 51) had insufficient sample sizes.

Thus, due to the lack of other subsamples, invariance across race could not be estimated for single mediator models at PR. For stage, models for Health (n = 57), Parent (n = 50), and Worksite (n = 28) had insufficient sample sizes. Invariance for stage was assessed through two modifications of the study variable: study with only Patient and RDD studies (Study, 2 subgroups) and study with Health, Parent, and Worksite studies combined to create a third subgroup (combined n = 57 + 50 + 28 = 135; Study, combined). For all models and all variables, Strict Factorial Invariance held across the subgroups with a very good fit (NFI > 0.095, CFI > 0.095, RMSEA < 0.05; see Table 6.8).

Discussion

Factorial invariance techniques were utilized to test for moderation in a series of 20 statistical mediation models (Table 6.1). Five subgrouping variables were investigated as potential moderators in each of these models. Evidence of Strict Factorial Invariance was found across all models for all subgroup comparisons, suggesting that the mechanisms of behavior change for smoking described by the statistical mediation models were robust across the characteristics of the sample. These models showed evidence of generalizability across study, age, education, gender, and race.

Patterns of Invariance

All 20 statistical mediation models, including multiple mediator models, multiple IV models, and single mediator models demonstrated Strict Factorial Invariance across all subgroups for participants beginning intervention in PC, C, and PR. Demographics, including age group, education level, gender, and race, did not demonstrate any evidence of moderation. The TTM-tailored smoking cessation interventions that made up the combined samples were designed to be administered to the general population of smokers, and the evidence for Strict Factorial Invariance supports the generalizability of these intervention materials. Models across subgroups for the original studies (Health, Patient, Parent, RDD, and Worksite) also did not demonstrate any evidence of moderation. The consistent result of Strict Factorial Invariance across the studies

provides important evidence for the validity of combining these studies to develop the statistical mediation models.

Limitations

Despite consistently demonstrating Strict Factorial Invariance, analyses across race subgroups sometimes produced comparatively low fit indices. All fits were good or better (lowest NFI for race = 0.927), but they still may suggest some slight differences across subgroups. Better understanding these patterns could be a focus of a future study; while overall sample sizes across PC, C, and PR were very large in the present study, the diversity of the samples was limited. Each of the five studies was primarily white, and as a result the combined samples were approximately 90% white. The only way to have enough participants to run invariance analyses was to group all non-white participants into a single group, and this was still not large enough to run models at PR. This approach was necessary to run analyses, but it was suboptimal for investigating racial differences related to cigarette smoking.

Another disadvantage to the primarily white, non-Hispanic sample was that sample sizes for individuals that identified as Hispanic were insufficient for analysis. Multicultural research on smoking has suggested that there are racial and ethnic differences related to multiple aspects of cigarette smoking. Smoking rates vary across races and ethnicities; Hispanics are less likely to be smokers than whites or Caucasians and blacks or African Americans (CDC, 2011a; CDC, 2011b). There is also evidence that smoking cessation efforts may have differential impacts depending on the racial and ethnic demographics of the sample. Population-based studies have shown that blacks or African Americans and Hispanics are less likely to quit smoking after smoking cessation interventions (Gundersen, Delnevo, & Wackowski, 2009; Kendzor et al., 2008; Piper et al., 2010; Trinidad et al., 2011). A substantially more diverse sample, with more participants of different races and different ethnicities, would provide new opportunities for invariance testing that could more comprehensively investigate these potential differences and improve the validity of these statistical mediation models. A diverse, international sample would further increase the

generalizability of the results, and the results would better represent the true underlying mechanisms of smoking behavior change.

Model fits from SEM for all statistical mediation models were based on covariance matrices. Mean structures were not estimated because the primary goal of statistical mediation model building was to describe the relations among patterns of variables, not differences in means. In the present study, some subgrouping variables were possibly associated with differences in means. To estimate mean structures, all of the 20 final mediation models would need to be re-specified and rerun. Then, an additional series of invariance analyses could be performed across all mediation models and subgroups. This new level of invariance, which would add an additional level of constraints beyond Strict Factorial Invariance, would test for mean differences across subgroups. Alternatively, other statistical methods could be utilized to investigate differences in means over time. Repeated measures MANOVA, for example, could be employed to estimate mean differences over time for manifest variables. These analyses, which are ancillary to the goals of the present series of statistical mediation analyses, could be explored in future studies.

Future Directions

Answering mediation questions involves describing how variables cause changes in other variables. The series of statistical mediation analyses tested in the present study provided evidence that the processes changed the mediators, which in turn changed the smoking outcome, but the evidence for casualty could be augmented with additional investigations. While many arguments for causality derive from general guidelines, such as temporality (the cause should come before the effect in time), some modern techniques have been specifically developed to evaluate empirical evidence of causality. Some of these methods, which are grounded in the framework of the Rubin Causal Model (Holland, 1988; Rubin, 1974; 1977), include the use of instrumental variables (Angrist & Krueger, 2001), principle stratification (Frangakis & Rubin, 2002), and propensity score matching (Coffman, 2011; Jo, Stuart, MacKinnon, & Vinokur, 2011;

Rosenbaum & Rubin, 1983). These techniques can be adapted to mediation analyses, although such efforts would differ greatly from the mediation models described in the present study. Future studies, focusing entirely on investigating causality, could produce compelling results that would supplement (but not replace) the results of the present series of studies.

Conclusions

Findings from a comprehensive series of statistical mediation analyses were further validated by testing for the presence of moderator variables. All 20 mediation models were found to be robust across a variety of subgrouping variables. Testing invariance across these final models provides critical evidence of the validity, generalizability, and usefulness of these final models. Ultimately, these mediation models represent mediating mechanisms that drove the observed changes in smoking behavior in five TTM-tailored smoking interventions. These insights into the mechanisms of smoking behavior change are important to both basic knowledge of smoking behavior and to the improvement and refinement of smoking cessation interventions.

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Table 6.1. Summary of multiple mediator models, models with multiple processes of change, and single mediator models that demonstrated evidence of statistical mediation (abbreviations used in other tables are included in parentheses), with products of standardized longitudinal regression paths

Independent Variable(s)	Mediator(s)	Product of Std. Reg. Paths
Multiple Mediator Models at PC		
Consciousness Raising (CR)	Pros of Smoking (Pros) &	0.101
	Situational Temptations (ST)	0.206
Dramatic Relief (DR)	Pros of Smoking (Pros) &	0.108
	Situational Temptations (ST)	0.192
Environmental Reevaluation (ER)	Cons of Smoking (Cons) &	0.027
	Situational Temptations (ST)	0.037
Multiple IV Models at PC		
Consciousness Raising (CR) &	Pros of Smoking (Pros)	0.083
Social Liberation (SO)		0.079
Dramatic Relief (DR) &	Pros of Smoking (Pros)	0.051
Social Liberation (SO)		0.094
Self-Reevaluation (SR) &	Pros of Smoking (Pros)	0.068
Social Liberation (SO)		0.092
Environmental Reevaluation (ER) &	Cons of Smoking (Cons)	0.039
Social Liberation (SO)		0.082
Single Mediator Models at PC		
Helping Relationships (HR)	Cons of Smoking (Cons)	0.034
Self Liberation (SL)	Cons of Smoking (Cons)	0.040
Self-Reevaluation (SR)	Cons of Smoking (Cons)	0.089
Multiple IV Models at C		
Consciousness Raising (CR) &	Pros of Smoking (Pros)	0.147
Self-Reevaluation (SR) &		0.093
Counter Conditioning (CC)		-0.169
Dramatic Relief (DR) &	Pros of Smoking (Pros)	0.155
Counter Conditioning (CC)		-0.159
Environmental Reevaluation (ER) &	Pros of Smoking (Pros)	0.075
Counter Conditioning (CC)		-0.140
Self-Reevaluation (SR) &	Situational Temptations (ST)	0.089
Stimulus Control (SC)		-0.058
Self-Reevaluation (SR) &	Pros of Smoking (Pros)	0.078
Social Liberation (SO)		0.046
Single Mediator Models at C		
Counter Conditioning (CC)	Situational Temptations (ST)	-0.052
Environmental Reevaluation (ER)	Cons of Smoking (Cons)	0.025
Social Liberation (SO)	Cons of Smoking (Cons)	0.063
Self-Reevaluation (SR)	Cons of Smoking (Cons)	0.055
Single Mediator Models at PR		
Self-Reevaluation (SR)	Situational Temptations (ST)	0.133

Table 6.2. Sample sizes for participants in PC, C, and PR at baseline for subgroups involved in invariance testing

Variable	**Subgroup**	**PC *n***	**C *n***	**PR *n***
Age (years)	18 – 34	335	349	151
	35 – 44	359	403	162
	45 – 54	234	263	97
	≥ 55	213	220	88
Education Level (years)	≤ 12	677	632	255
	13 – 15	273	340	139
	≥ 16	165	233	91
Gender	Female	717	770	291
	Male	429	473	208
Race	White	1062	1145	448
	Non-White	84	98	51
Study	Health	173	166	57
	Patient	177	287	136
	Parent	153	145	50
	RDD	565	565	228
	Worksite	77	80	28
Stage of Change	Precontemplation	1145		
	Contemplation		1243	
	Preparation			499

Table 6.3. Goodness-of-fit statistics for Strict Factorial Invariance; multiple mediator models at PC

Subgroup	χ^2	(df)	NFI	CFI	RMSEA	(90% RMSEA)
Model: CR – Pros & ST						
Age	3512.171	(1739)	0.919	1.000	0.000	-
Education	2597.127	(1274)	0.944	1.000	0.000	-
Gender	2164.348	(809)	0.937	1.000	0.000	-
Race	2267.176	(809)	0.927	1.000	0.000	(0.000, 0.011)
Study, 4 subgroups[1]	3649.572	(1739)	0.955	1.000	0.000	-
Study, combined[2]	3687.369	(1739)	0.987	1.000	0.000	-
Model: DR – Pros & ST						
Age	3646.175	(1739)	0.932	1.000	0.000	-
Education	2789.333	(1274)	0.949	1.000	0.000	-
Gender	2248.024	(809)	0.942	1.000	0.000	-
Race	1616.274	(809)	1.000	1.000	0.000	(0.000, 0.012)
Study, 4 subgroups[1]	3720.343	(1739)	0.959	1.000	0.000	-
Study, combined[2]	3757.561	(1739)	0.962	1.000	0.000	-
Model: ER – Cons & ST						
Age	2702.017	(1739)	0.975	1.000	0.000	-
Education	2054.620	(1274)	0.998	1.000	0.000	-
Gender	1358.501	(809)	0.991	1.000	0.000	-
Race	1657.896	(809)	0.984	1.000	0.000	-
Study, 4 subgroups[1]	2963.078	(1739)	0.993	1.000	0.000	-
Study, combined[2]	2919.863	(1739)	1.000	1.000	0.000	-

- Lower confidence limit negative, interval not calculated

[1]Worksite study excluded; convergence issues due to small sample size and complex model

[2]Worksite study combined with second-smallest sample (Parent study), 4 subgroups

Table 6.4. Goodness-of-fit statistics for Strict Factorial Invariance; multiple IV models at PC

Subgroup	χ^2	(df)	NFI	CFI	RMSEA	(90% RMSEA)
Model: CR & SO – Pros						
Age	2011.379	(1402)	1.000	1.000	0.000	-
Education	1502.440	(1024)	0.983	1.000	0.000	-
Gender	1030.271	(646)	0.979	1.000	0.000	-
Race	985.949	(646)	0.957	1.000	0.000	-
Study, 4 subgroups[1]	2175.613	(1402)	0.983	1.000	0.000	-
Study, combined[2]	2168.207	(1402)	1.000	1.000	0.000	-
Model: DR & SO – Pros						
Age	1949.177	(1402)	0.996	1.000	0.000	-
Education	1349.635	(1024)	1.000	1.000	0.000	-
Gender	905.215	(646)	1.000	1.000	0.000	-
Race	942.331	(646)	0.982	1.000	0.000	-
Study, 4 subgroups[1]	1979.263	(1402)	0.997	1.000	0.000	-
Study, combined[2]	1970.078	(1402)	1.000	1.000	0.000	-
Model: SR & SO – Pros						
Age	2023.527	(1402)	1.000	1.000	0.000	-
Education	1404.158	(1024)	0.994	1.000	0.000	-
Gender	983.428	(646)	1.000	1.000	0.000	-
Race	1270.227	(646)	0.969	1.000	0.000	-
Study, 4 subgroups[1]	2101.831	(1402)	0.997	1.000	0.000	-
Study, combined[2]	2137.299	(1402)	1.000	1.000	0.000	-
Model: ER & SO – Cons						
Age	1889.889	(1402)	1.000	1.000	0.000	-
Education	1473.722	(1024)	1.000	1.000	0.000	-
Gender	917.856	(646)	1.000	1.000	0.000	-
Race	1035.438	(646)	0.979	1.000	0.000	-
Study, 4 subgroups[1]	2100.331	(1402)	1.000	1.000	0.000	-
Study, combined[2]	2082.400	(1402)	1.000	1.000	0.000	-

- Lower confidence limit negative, interval not calculated

[1]Worksite study excluded; convergence issues due to small sample size and complex model

[2]Worksite study combined with second-smallest sample (Parent study), 4 subgroups

Table 6.5. Goodness-of-fit statistics for Strict Factorial Invariance; single mediator models at PC

Subgroup	χ^2	(df)	NFI	CFI	RMSEA	(90% RMSEA)
Model: HR – Cons						
Age	1091.928	(842)	1.000	1.000	0.000	-
Education	785.794	(609)	1.000	1.000	0.000	-
Gender	502.442	(380)	1.000	1.000	0.000	-
Race	541.831	(380)	0.997	1.000	0.000	-
Study	750.128	(1071)	1.000	1.000	0.000	-
Model: SL – Cons						
Age	1079.812	(842)	1.000	1.000	0.000	-
Education	828.606	(609)	1.000	1.000	0.000	-
Gender	526.494	(380)	1.000	1.000	0.000	-
Race	600.302	(380)	0.986	1.000	0.000	-
Study	892.254	(1071)	1.000	1.000	0.000	-
Model: SR – Cons						
Age	1192.551	(842)	1.000	1.000	0.000	-
Education	866.856	(609)	1.000	1.000	0.000	-
Gender	531.630	(380)	0.998	1.000	0.000	-
Race	602.032	(380)	0.984	1.000	0.000	-
Study	1690.033	(1071)	1.000	1.000	0.000	-

- Lower confidence limit negative, interval not calculated

Table 6.6. Goodness-of-fit statistics for Strict Factorial Invariance; multiple IV models at C

Subgroup	χ^2	(df)	NFI	CFI	RMSEA	(90% RMSEA)
Model: CR & SR & CC – Pros						
Age	3475.086	(1974)	1.000	1.000	0.000	-
Education	2633.636	(1409)	0.973	1.000	0.000	-
Gender	2145.785	(984)	0.972	1.000	0.000	-
Race	2664.920	(984)	0.955	1.000	0.000	-
Study, 4 subgroups[1]	3749.586	(1974)	0.976	1.000	0.000	-
Study, combined[2]	3794.683	(1974)	0.977	1.000	0.000	-
Model: DR & CC – Pros						
Age	2094.719	(1402)	1.000	1.000	0.000	-
Education	1603.075	(1024)	0.983	1.000	0.000	-
Gender	1163.499	(646)	0.985	1.000	0.000	-
Race	999.303	(646)	1.000	1.000	0.000	-
Study	1073.125	(1780)	0.996	1.000	0.000	-
Model: ER & CC – Pros						
Age	2055.391	(1402)	1.000	1.000	0.000	-
Education	1485.789	(1024)	0.991	1.000	0.000	-
Gender	1925.234	(646)	0.983	1.000	0.000	-
Race	1120.991	(646)	0.973	1.000	0.000	-
Study	951.919	(1780)	1.000	1.000	0.000	-
Model: SR & SC – ST						
Age	2415.946	(1402)	0.988	1.000	0.000	-
Education	1817.765	(1024)	0.959	1.000	0.000	-
Gender	1403.932	(646)	0.961	1.000	0.000	-
Race	775.910	(646)	0.958	1.000	0.000	-
Study	3108.585	(1780)	0.994	1.000	0.000	-
Model: SR & SO – Pros						
Age	2146.882	(1402)	1.000	1.000	0.000	-
Education	1695.218	(1024)	0.977	1.000	0.000	-
Gender	1237.804	(646)	0.968	1.000	0.000	-
Race	1385.733	(646)	0.962	1.000	0.000	-
Study	995.498	(1780)	1.000	1.000	0.000	-

- Lower confidence limit negative, interval not calculated

[1]Worksite study excluded; convergence issues due to small sample size and complex model

[2]Worksite study combined with second-smallest sample (Parent study), 4 subgroups

Table 6.7. Goodness-of-fit statistics for Strict Factorial Invariance; single mediator models at C

Subgroup	χ^2	(df)	NFI	CFI	RMSEA	(90% RMSEA)
Model: CC – ST						
Age	1467.957	(842)	0.971	1.000	0.000	-
Education	1103.369	(609)	0.960	1.000	0.000	-
Gender	817.491	(380)	0.963	1.000	0.000	-
Race	505.367	(380)	0.958	1.000	0.000	(0.000, 0.011)
Study	1758.274	(1071)	0.993	1.000	0.000	-
Model: ER – Cons						
Age	1093.436	(842)	1.000	1.000	0.000	-
Education	777.384	(609)	0.989	1.000	0.000	-
Gender	808.513	(380)	0.958	1.000	0.000	(0.000, 0.006)
Race	679.838	(380)	0.983	1.000	0.000	-
Study	648.700	(1071)	0.998	1.000	0.000	-
Model: SO – Cons						
Age	1135.558	(842)	0.984	1.000	0.000	-
Education	1102.465	(609)	0.945	1.000	0.000	-
Gender	585.103	(380)	0.996	1.000	0.000	-
Race	628.653	(380)	1.000	1.000	0.000	(0.000, 0.014)
Study	1806.716	(1071)	0.987	1.000	0.000	-
Model: SR – Cons						
Age	1163.366	(842)	0.998	1.000	0.000	-
Education	893.498	(609)	0.986	1.000	0.000	-
Gender	687.557	(380)	0.988	1.000	0.000	-
Race	752.552	(380)	0.981	1.000	0.000	-
Study	1941.951	(1071)	0.966	1.000	0.000	-

- Lower confidence limit negative, interval not calculated

Table 6.8. Goodness-of-fit statistics for Strict Factorial Invariance; single mediator models at PR

Subgroup	χ^2	(df)	NFI	CFI	RMSEA	(90% RMSEA)
Model: SR – ST						
Age	1294.873	(842)	0.975	1.000	0.000	-
Education	866.976	(609)	1.000	1.000	0.000	-
Gender	502.918	(380)	1.000	1.000	0.000	-
Race[1]						
Study, 2 subgroups[2]	557.492	(380)	1.000	1.000	0.000	-
Study, combined[3]	827.108	(609)	1.000	1.000	0.000	-

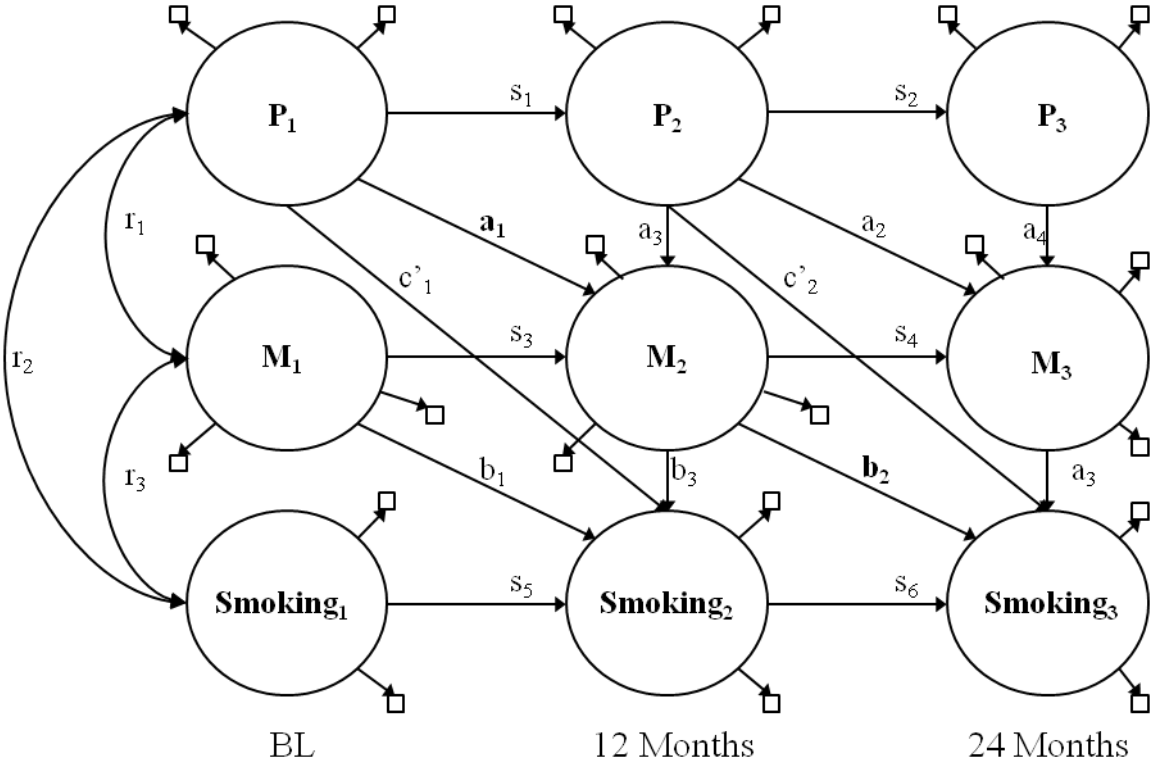
- Lower confidence limit negative, interval not calculated

[1]Invariance across race could not be tested due to inadequate sample sizes

[2]Health, Parent, and Worksite studies excluded due to small sample sizes

[3]Health, Parent, and Worksite studies combined to create a large enough group, 3 subgroups

Figure 6.1. Autoregressive mediation model II template, with Processes of Change (P) as independent variables, mediating variables (M) as mediators, and smoking outcome (Smoking) as dependent variables; at the baseline, 12-month, and 24-month time points



CONCLUSIONS FROM STUDIES

The overarching goal of the series of six studies was to investigate the mechanisms of behavior change for smoking with statistical mediation analysis. Studies 1, 2, and 3 focused on single mediator models and evaluated mediation within the pre-action stages of change, Precontemplation (PC), Contemplation (C), and Preparation (PR). Across the three stages, a total of 25 single mediator models, each with different combinations of variables, demonstrated evidence of statistical mediation. Studies 4 and 5 built on the results of the single mediator models to develop models with multiple mediators and multiple processes of change and resulted in a total of 20 final models. Testing invariance across these final models, in study 6, provided critical evidence of the validity, generalizability, and usefulness of these final models.

These final models varied in how strongly they represent the mechanisms of behavior change for smoking. They can be organized into three tiers. The first tier includes multiple mediator models. There were three multiple mediator models found at PC (Table 6.1). These models provided the strongest evidence of the mechanisms of behavior change for smoking because they involved processes of change that were strong enough to simultaneously influence two mediators, as well as mediators that were strong enough to coexist in the same model. Among these multiple mediator models (only at PC), the strongest mediation pathways, based on effect sizes, were associated with Consciousness Raising, Dramatic Relief, the Pros of Smoking, and Situational Temptations to Smoke.

The second tier includes multiple IV models. There were four multiple IV models found at PC and five multiple IV models found at C. These models provided strong evidence of the mechanisms of behavior change for smoking because they involved processes of change that were strong enough to demonstrate statistical mediation simultaneously with other processes in the model. Many of the processes of change involved with these multiple IV models demonstrated strong mediation pathways, with medium to large effect sizes, such as

Consciousness Raising, Self-Reevaluation, and Social Liberation. The most important mediator was the Pros of Smoking.

The third tier includes single mediator models. In some cases, these models included combinations of variables that no longer demonstrated evidence of statistical mediation when combined into multiple mediator or multiple IV models; in other cases, there were simply no opportunities to combine these models. These models each provided evidence of the mechanisms of behavior change. Some of these single mediator models demonstrated strong mediation pathways, such as Self-Reevaluation through the Cons of Smoking at PC and Situational Temptations at PR.

In total, nine out of ten Processes of Change for Smoking (all but Reinforcement Management) and all three hypothesized mediators were involved in at least one model that demonstrated evidence of statistical mediation. Pros of Smoking, Cons of Smoking, and Situational Temptations to Smoke were all found to mediate smoking behavior, with different combinations of Processes, for individuals in both PC and C. The most important Processes of Change for individuals in PC included Consciousness Raising, Dramatic Relief, Environmental Reevaluation, Self-Reevaluation, and Social Liberation. The most important Processes of Change for individuals in C included Counter Conditioning, Consciousness Raising, Dramatic Relief, Environmental Reevaluation, Self-Reevaluation, Social Liberation, and Stimulus Control. For individuals in PR, Self-Reevaluation was found to mediate smoking behavior through Situational Temptations.

Interpreting the results by stage of change is not only helpful for organizational purposes but also directly relates to increasing understanding of how these mechanisms relate to successful interventions. Better understanding which processes of change and mediators are most important and most relevant for individuals at certain levels of readiness to change can directly contribute to future intervention efforts. Interventions can be individually tailored to focus on variables most likely to have the biggest effects on behavioral outcomes. Modern, computerized interventions

can adapt to make intervention contacts as relevant as possible by tailoring to individuals to focus on which behavioral mechanisms are the most important to changing behavior. For example, results from the present series of analyses suggest that individuals beginning an intervention in PC should be encouraged to utilize strategies involving Consciousness Raising and Dramatic Relief. Participants beginning an intervention in PC are not intending to quit smoking, and are not yet ready for behavioral strategies, such as Counter Conditioning and Stimulus Control.

The most important test of the usefulness and generalizability of the statistical mediation models assessed in the present series of studies would involve directly applying the results to interventions. If an intervention group that received behavioral mechanism-based tailoring outperformed a group with less specific tailoring, this finding would both help validate the overall approach and create the opportunity for further intervention refinement. Future mediation analyses could evaluate these interventions, and a cycle of continued refinement and testing with statistical mediation analysis could be implemented. Ultimately, faster and more effective interventions could be developed.

APPENDIX A

Measures Utilized Across All Studies

Appendix A.1. Smoking: Stage of Change items

1. Are you currently a smoker?

- Yes, I currently smoke
- No, I quit within the last 6 months (*Action stage*)
- No, I quit more than 6 months ago (*Maintenance stage*)
- No, I have never smoked (*Nonsmoker*)

2. (For smokers) In the last year, how many times have you quit smoking for at least 24 hours?

3. (For smokers) Are you seriously thinking of quitting smoking?

- Yes, within the next 30 days (*Preparation stage* if they have one 24-hour quit attempt in the past year; refer to previous question, if no quit attempt then *Contemplation stage*)
- Yes, within the next 6 months (*Contemplation stage*)
- No, not thinking of quitting (*Precontemplation stage*)

Appendix A.2. Processes of Change for Smoking items

The following experiences can affect the smoking habits of some people. Think of any similar experiences you may be currently having or have had in the last month. Then rate the FREQUENCY of this event on the following five point scale.

1 = Never 2 = Seldom 3 = Occasionally 4 = Often 5 = Repeatedly

Consciousness Raising ($\alpha = 0.61$)

- I recall information people have given me on the benefits of quitting smoking.
- I think about information from articles and ads about how to stop smoking.

Dramatic Relief ($\alpha = 0.72$)

- Warnings about the health hazards of smoking move me emotionally.
- I react emotionally to warnings about smoking cigarettes.

Environmental Reevaluation ($\alpha = 0.84$)

- I stop to think that smoking is polluting the environment.
- I consider the view that smoking can be harmful to the environment.

Self-Reevaluation ($\alpha = 0.79$)

- I get upset when I think about my smoking.
- My need for cigarettes makes me feel disappointed in myself.

Social Liberation ($\alpha = 0.64$)

- I notice that nonsmokers are asserting their rights.
- I find society changing in ways that makes it easier for nonsmokers.

Appendix A.2. Processes of Change for Smoking items (continued)

Counter Conditioning (α = 0.60)

- When I am tempted to smoke I think about something else.
- I do something else instead of smoking when I need to relax.

Helping Relationships (α = 0.78)

- I have someone who listens when I need to talk about my smoking.
- I have someone I can count on when I'm having problems with smoking.

Reinforcement Management (α = 0.77)

- I can expect to be rewarded by others if I don't smoke.
- I am rewarded by others if I don't smoke.

Self Liberation (α = 0.71)

- I tell myself I can quit if I want to.
- I tell myself that if I try hard enough I can keep from smoking.

Stimulus Control (α = 0.64)

- I remove things from my home or place of work that remind me of smoking.
- I keep things around my home or place of work that remind me not to smoke.

Appendix A.3. Decisional Balance for Smoking items

The following statements represent different opinions about smoking. Please rate HOW IMPORTANT each statement is to your decision to smoke according to the following five point scale.

1 = Not important 2 = Slightly important 3 = Moderately important

4 = Very important 5 = Extremely important

Pros ($\alpha = 0.70$)

- Smoking cigarettes relieves tension.
- Smoking helps me concentrate and do better work.
- I am relaxed and therefore more pleasant when smoking.

Cons ($\alpha = 0.66$)

- I'm embarrassed to have to smoke.
- My cigarette smoking bothers other people.
- People think I'm foolish for ignoring the warnings about cigarette smoking.

Appendix A.4. Situational Temptations to Smoke items

Listed below are situations that lead some people to smoke. We would like to know HOW TEMPTED you may be to smoke in each situation. Please answer the following questions using the following five point scale.

1 = Not at all tempted 2 = Not very tempted 3 = Moderately tempted

4 = Very tempted 5 = Extremely tempted

Positive Affect / Social Situations

- With friends at a party.
- Over coffee while talking and relaxing.
- With my spouse or close friend who is smoking.

Negative Affect Situations

- When I am very anxious and stressed.
- When I am very angry about something or someone.
- When things are not going my way and I am frustrated.

Habitual / Craving Situations

- When I first get up in the morning.
- When I feel I need a lift.
- When I realize I haven't smoked for a while.

Coefficient alpha for Situational Temptations to Smoke = 0.78

Appendix A.5. Smoking Outcome items

1. Time to first cigarette

Original question: How soon after you wake do you usually smoke your first cigarette?

Response categories created from available data (with new 1-5 scale value):

- Nonsmoker (1)
- After 60 minutes (2)
- 31-60 minutes (3)
- 5-30 minutes (4)
- Within 5 minutes (5)

2. Number of cigarettes per day

Original question: During the past 7 days how many cigarettes did you smoke on a typical day?

Response categories created from available data (with new 1-5 scale value):

- 0 (Nonsmoker) (1)
- 1-10 (2)
- 11-20 (3)
- 21-30 (4)
- 31 or more (5)

Coefficient alpha for Smoking Outcome = 0.75

APPENDIX B

Correlation Matrices for Variables in Final Models

Appendix B.1. Summary of abbreviations used in correlation matrices (PC, C, and PR)

Abbreviation	Variable
Smk	Smoking outcome
Pros	Pros of Smoking
Cons	Cons of Smoking
ST	Situational Temptations
CC	Counter Conditioning
CR	Consciousness Raising
DR	Dramatic Relief
ER	Environmental Reevaluation
HR	Helping Relationships
SC	Stimulus Control
SL	Self-Liberation
SO	Social Liberation
SR	Self-Reevaluation
BL	Baseline
12	12 months
24	24 months

Appendix B.2.Correlation matrix of averages for variables in final models for PC (part 1 of 2)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Smk BL	1.00																	
2. Smk 12	0.58	1.00																
3. Smk 24	0.46	0.58	1.00															
4. Pros BL	0.29	0.22	0.18	1.00														
5. Pros 12	0.22	0.34	0.20	0.54	1.00													
6. Pros 24	0.22	0.31	0.39	0.48	0.60	1.00												
7. Cons BL	0.00	0.02	-0.01	0.22	0.14	0.12	1.00											
8. Cons 12	0.04	0.07	0.01	0.17	0.31	0.20	0.52	1.00										
9. Cons 24	0.05	0.12	0.17	0.11	0.19	0.35	0.41	0.58	1.00									
10. ST BL	0.45	0.36	0.29	0.56	0.40	0.38	0.23	0.15	0.17	1.00								
11. ST 12	0.36	0.56	0.41	0.35	0.59	0.48	0.13	0.26	0.27	0.55	1.00							
12. ST 24	0.31	0.45	0.64	0.35	0.40	0.62	0.10	0.17	0.34	0.51	0.66	1.00						
13. CR BL	-0.02	0.00	-0.02	0.12	0.07	0.08	0.37	0.33	0.22	0.14	0.03	0.05	1.00					
14. CR 12	0.02	0.03	-0.06	0.10	0.18	0.07	0.28	0.48	0.32	0.12	0.13	0.07	0.40	1.00				
15. CR 24	-0.01	0.07	0.00	0.11	0.19	0.15	0.25	0.38	0.43	0.13	0.23	0.15	0.41	0.49	1.00			
16. DR BL	-0.10	-0.07	-0.08	0.13	0.11	0.07	0.40	0.37	0.29	0.11	0.03	0.07	0.44	0.29	0.34	1.00		
17. DR 12	-0.01	0.00	-0.10	0.11	0.19	0.13	0.29	0.47	0.35	0.09	0.11	0.09	0.30	0.54	0.44	0.47	1.00	
18. DR 24	-0.06	0.01	-0.04	0.10	0.15	0.13	0.22	0.35	0.44	0.11	0.15	0.11	0.32	0.40	0.60	0.47	0.57	1.00
19. ER BL	-0.16	-0.10	-0.08	0.08	0.04	0.06	0.33	0.31	0.28	0.06	-0.02	0.05	0.41	0.27	0.27	0.42	0.28	0.27
20. ER 12	-0.02	-0.02	-0.07	0.03	0.11	0.02	0.23	0.42	0.32	0.03	0.07	0.05	0.20	0.44	0.38	0.32	0.51	0.34
21. ER 24	-0.06	-0.04	-0.04	0.09	0.15	0.11	0.22	0.35	0.40	0.08	0.10	0.08	0.27	0.31	0.55	0.37	0.37	0.59
22. HR BL	-0.10	-0.03	-0.08	0.02	-0.02	-0.02	0.17	0.14	0.12	0.04	-0.02	-0.02	0.29	0.17	0.21	0.20	0.10	0.13
23. HR 12	0.01	-0.05	-0.07	0.03	0.01	0.04	0.19	0.24	0.23	0.09	0.00	0.01	0.14	0.33	0.19	0.14	0.22	0.18
24. HR 24	-0.02	-0.04	-0.11	0.03	0.03	0.00	0.15	0.16	0.21	0.08	0.03	-0.04	0.16	0.25	0.33	0.19	0.21	0.30
25. SL BL	-0.21	-0.12	-0.13	0.00	-0.07	-0.11	0.18	0.11	0.14	-0.03	-0.11	-0.09	0.34	0.18	0.19	0.29	0.10	0.22
26. SL 12	-0.14	-0.26	-0.22	-0.07	-0.05	-0.11	0.09	0.20	0.08	-0.04	-0.14	-0.15	0.22	0.42	0.24	0.19	0.31	0.22
27. SL 24	-0.13	-0.14	-0.23	-0.01	0.06	-0.02	0.08	0.20	0.24	-0.01	-0.02	-0.08	0.19	0.31	0.38	0.19	0.26	0.40
28. SO BL	-0.03	0.05	0.00	0.10	0.07	0.07	0.25	0.17	0.15	0.10	0.14	0.09	0.31	0.15	0.18	0.18	0.17	0.14
29. SO 12	0.08	0.18	0.10	0.06	0.19	0.13	0.19	0.33	0.30	0.16	0.25	0.18	0.15	0.35	0.25	0.14	0.25	0.16
30. SO 24	0.04	0.16	0.10	0.06	0.14	0.13	0.11	0.23	0.32	0.15	0.26	0.18	0.15	0.18	0.31	0.12	0.10	0.26
31. SR BL	0.04	0.05	0.01	0.17	0.12	0.12	0.49	0.40	0.38	0.22	0.15	0.16	0.46	0.28	0.32	0.56	0.37	0.43
32. SR 12	0.08	0.08	-0.03	0.11	0.20	0.12	0.34	0.55	0.42	0.16	0.20	0.12	0.29	0.53	0.43	0.37	0.65	0.48
33. SR 24	0.02	0.08	0.10	0.12	0.20	0.19	0.30	0.45	0.55	0.18	0.25	0.28	0.32	0.40	0.56	0.38	0.47	0.66

Appendix B.3. Covariance matrix of averages for variables in final models for PC (part 2 of 2)

	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1. Smk BL															
2. Smk 12															
3. Smk 24															
4. Pros BL															
5. Pros 12															
6. Pros 24															
7. Cons BL															
8. Cons 12															
9. Cons 24															
10. ST BL															
11. ST 12															
12. ST 24															
13. CR BL															
14. CR 12															
15. CR 24															
16. DR BL															
17. DR 12															
18. DR 24															
19. ER BL	1.00														
20. ER 12	0.45	1.00													
21. ER 24	0.46	0.52	1.00												
22. HR BL	0.24	0.13	0.12	1.00											
23. HR 12	0.17	0.23	0.12	0.46	1.00										
24. HR 24	0.12	0.16	0.24	0.46	0.56	1.00									
25. SL BL	0.29	0.13	0.19	0.26	0.12	0.15	1.00								
26. SL 12	0.19	0.24	0.18	0.16	0.27	0.19	0.41	1.00							
27. SL 24	0.18	0.15	0.31	0.11	0.07	0.28	0.35	0.47	1.00						
28. SO BL	0.19	0.09	0.16	0.15	0.11	0.16	0.18	0.07	0.08	1.00					
29. SO 12	0.16	0.23	0.17	0.07	0.19	0.17	0.03	0.18	0.09	0.39	1.00				
30. SO 24	0.14	0.07	0.30	0.08	0.13	0.18	0.09	0.07	0.23	0.37	0.46	1.00			
31. SR BL	0.35	0.26	0.27	0.21	0.13	0.14	0.31	0.18	0.16	0.19	0.15	0.15	1.00		
32. SR 12	0.24	0.45	0.29	0.10	0.23	0.19	0.13	0.35	0.26	0.13	0.27	0.12	0.53	1.00	
33. SR 24	0.21	0.29	0.42	0.16	0.20	0.26	0.20	0.24	0.36	0.16	0.23	0.27	0.55	0.59	1.00

Appendix B.4. Correlation matrix of averages for variables in final models for C (part 1 of 2)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Smk BL	1.00																	
2. Smk 12	0.47	1.00																
3. Smk 24	0.47	0.68	1.00															
4. Pros BL	0.21	0.17	0.12	1.00														
5. Pros 12	0.24	0.41	0.30	0.53	1.00													
6. Pros 24	0.21	0.31	0.40	0.50	0.59	1.00												
7. Cons BL	-0.01	0.02	0.02	0.21	0.08	0.09	1.00											
8. Cons 12	0.03	0.13	0.06	0.08	0.23	0.16	0.48	1.00										
9. Cons 24	0.02	0.13	0.17	0.07	0.17	0.31	0.40	0.55	1.00									
10. ST BL	0.41	0.28	0.21	0.54	0.36	0.33	0.17	0.09	0.06	1.00								
11. ST 12	0.29	0.61	0.46	0.36	0.67	0.51	0.13	0.26	0.22	0.49	1.00							
12. ST 24	0.29	0.53	0.66	0.30	0.50	0.67	0.09	0.19	0.32	0.41	0.68	1.00						
13. CC BL	-0.27	-0.15	-0.15	-0.10	-0.06	-0.08	0.12	0.12	0.04	-0.21	-0.13	-0.08	1.00					
14. CC 12	-0.16	-0.40	-0.34	-0.07	-0.19	-0.21	0.07	0.11	0.05	-0.10	-0.28	-0.26	0.33	1.00				
15. CC 24	-0.12	-0.21	-0.41	0.02	-0.04	-0.12	0.06	0.15	0.10	-0.02	-0.12	-0.23	0.25	0.37	1.00			
16. CR BL	-0.03	0.00	0.02	0.08	0.04	0.01	0.33	0.28	0.26	0.05	0.05	0.06	0.17	0.19	0.11	1.00		
17. CR 12	0.07	0.09	0.03	0.14	0.14	0.06	0.23	0.49	0.29	0.11	0.12	0.09	0.13	0.28	0.21	0.36	1.00	
18. CR 24	0.01	0.10	0.08	0.13	0.15	0.15	0.25	0.35	0.43	0.05	0.16	0.15	0.13	0.11	0.29	0.39	0.48	1.00
19. DR BL	-0.08	0.01	-0.06	0.12	0.02	0.06	0.37	0.29	0.32	0.07	0.04	0.03	0.20	0.13	0.07	0.40	0.31	0.32
20. DR 12	-0.07	0.00	-0.08	0.15	0.11	0.08	0.29	0.46	0.35	0.08	0.10	0.04	0.17	0.27	0.14	0.30	0.55	0.36
21. DR 24	-0.03	-0.01	-0.02	0.15	0.13	0.11	0.27	0.35	0.43	0.13	0.14	0.10	0.16	0.16	0.32	0.27	0.40	0.58
22. ER BL	-0.14	-0.04	-0.06	0.02	-0.07	-0.01	0.27	0.26	0.26	0.00	-0.06	0.00	0.23	0.14	0.09	0.34	0.26	0.26
23. ER 12	-0.06	-0.04	-0.06	0.03	-0.02	0.00	0.21	0.41	0.32	0.03	0.00	0.01	0.19	0.26	0.14	0.25	0.49	0.33
24. ER 24	-0.09	-0.03	-0.08	0.04	-0.02	0.04	0.23	0.32	0.36	0.01	0.04	0.01	0.19	0.16	0.24	0.25	0.35	0.45
25. SC BL	-0.18	-0.08	-0.08	0.02	0.03	-0.03	0.21	0.16	0.08	-0.05	0.01	-0.03	0.36	0.19	0.18	0.29	0.24	0.20
26. SC 12	-0.11	-0.20	-0.20	0.07	-0.02	-0.02	0.14	0.23	0.18	-0.02	-0.07	-0.09	0.20	0.45	0.26	0.22	0.42	0.28
27. SC 24	-0.07	-0.11	-0.22	0.06	0.01	0.00	0.17	0.23	0.24	0.03	0.03	-0.10	0.17	0.30	0.52	0.20	0.32	0.43
28. SL BL	-0.22	-0.11	-0.11	-0.02	-0.05	-0.07	0.12	0.11	0.06	-0.06	-0.05	-0.04	0.34	0.22	0.14	0.29	0.21	0.18
29. SL 12	-0.05	-0.19	-0.16	0.01	-0.06	-0.07	0.14	0.25	0.15	0.02	-0.08	-0.10	0.14	0.46	0.19	0.20	0.35	0.18
30. SL 24	-0.04	-0.07	-0.15	0.03	0.06	0.00	0.14	0.22	0.26	0.02	0.04	-0.02	0.15	0.25	0.46	0.19	0.26	0.42
31. SO BL	-0.02	0.01	-0.01	0.09	0.05	0.04	0.31	0.23	0.18	0.10	0.04	0.05	0.10	0.15	0.01	0.32	0.18	0.17
32. SO 12	0.04	0.13	0.09	0.06	0.17	0.11	0.19	0.42	0.29	0.10	0.19	0.17	0.00	0.14	0.01	0.16	0.39	0.22
33. SO 24	0.08	0.16	0.13	0.12	0.18	0.19	0.18	0.32	0.41	0.14	0.18	0.19	0.03	0.05	0.23	0.21	0.25	0.46
34. SR BL	0.02	0.08	0.01	0.18	0.17	0.17	0.45	0.37	0.40	0.16	0.16	0.17	0.15	0.10	0.12	0.39	0.34	0.29
35. SR 12	0.07	0.18	0.10	0.17	0.24	0.17	0.33	0.51	0.41	0.18	0.28	0.22	0.10	0.17	0.12	0.28	0.52	0.36
36. SR 24	0.08	0.22	0.21	0.14	0.25	0.27	0.34	0.42	0.54	0.19	0.32	0.36	0.06	0.01	0.19	0.25	0.35	0.51

Appendix B.5. Correlation matrix of averages for variables in final models for C (part 2 of 2)

	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1. Smk BL																		
2. Smk 12																		
3. Smk 24																		
4. Pros BL																		
5. Pros 12																		
6. Pros 24																		
7. Cons BL																		
8. Cons 12																		
9. Cons 24																		
10. ST BL																		
11. ST 12																		
12. ST 24																		
13. CC BL																		
14. CC 12																		
15. CC 24																		
16. CR BL																		
17. CR 12																		
18. CR 24																		
19. DR BL	1.00																	
20. DR 12	0.54	1.00																
21. DR 24	0.48	0.54	1.00															
22. ER BL	0.42	0.31	0.29	1.00														
23. ER 12	0.30	0.53	0.38	0.51	1.00													
24. ER 24	0.30	0.36	0.52	0.52	0.66	1.00												
25. SC BL	0.32	0.26	0.23	0.26	0.21	0.23	1.00											
26. SC 12	0.28	0.42	0.31	0.19	0.35	0.25	0.41	1.00										
27. SC 24	0.23	0.32	0.47	0.17	0.28	0.40	0.35	0.50	1.00									
28. SL BL	0.26	0.24	0.19	0.23	0.19	0.18	0.25	0.18	0.12	1.00								
29. SL 12	0.19	0.33	0.23	0.16	0.33	0.16	0.15	0.32	0.21	0.40	1.00							
30. SL 24	0.17	0.26	0.42	0.11	0.20	0.29	0.13	0.23	0.42	0.30	0.44	1.00						
31. SO BL	0.23	0.18	0.10	0.19	0.15	0.18	0.14	0.16	0.09	0.15	0.11	0.09	1.00					
32. SO 12	0.15	0.32	0.14	0.14	0.32	0.16	0.03	0.13	0.06	0.09	0.25	0.14	0.29	1.00				
33. SO 24	0.16	0.19	0.33	0.17	0.24	0.33	0.05	0.08	0.20	0.05	0.14	0.32	0.30	0.50	1.00			
34. SR BL	0.55	0.43	0.41	0.35	0.29	0.28	0.29	0.28	0.24	0.25	0.18	0.18	0.29	0.19	0.21	1.00		
35. SR 12	0.38	0.58	0.41	0.20	0.39	0.26	0.20	0.35	0.28	0.15	0.36	0.24	0.14	0.34	0.27	0.55	1.00	
36. SR 24	0.36	0.39	0.60	0.23	0.28	0.43	0.15	0.18	0.38	0.11	0.18	0.42	0.16	0.20	0.40	0.53	0.54	1.00

Appendix B.6. Correlation matrix of averages for variables in final models for PR

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Smk BL	1.00														
2. Smk 12	0.49	1.00													
3. Smk 24	0.49	0.72	1.00												
4. Pros BL	0.32	0.22	0.26	1.00											
5. Pros 12	0.19	0.36	0.41	0.45	1.00										
6. Pros 24	0.32	0.31	0.46	0.44	0.56	1.00									
7. Cons BL	0.01	0.06	0.09	0.20	0.15	0.14	1.00								
8. Cons 12	0.02	0.11	0.13	0.22	0.27	0.15	0.54	1.00							
9. Cons 24	0.06	0.16	0.24	0.20	0.24	0.36	0.52	0.58	1.00						
10. ST BL	0.49	0.27	0.39	0.55	0.34	0.45	0.20	0.19	0.24	1.00					
11. ST 12	0.35	0.64	0.55	0.31	0.62	0.51	0.14	0.24	0.30	0.47	1.00				
12. ST 24	0.33	0.47	0.68	0.31	0.48	0.66	0.16	0.26	0.43	0.49	0.70	1.00			
13. SR BL	0.06	0.06	0.13	0.20	0.15	0.17	0.47	0.41	0.36	0.27	0.12	0.19	1.00		
14. SR 12	0.06	0.16	0.20	0.16	0.28	0.25	0.29	0.52	0.40	0.20	0.28	0.33	0.54	1.00	
15. SR 24	0.13	0.16	0.25	0.17	0.24	0.40	0.28	0.34	0.58	0.24	0.22	0.43	0.43	0.61	1.00