UW Biostatistics Working Paper Series

3-16-2010

Using the Stages of Change Model to Choose an Optimal Health Marketing Target

Paula Diehr
University of Washington, pdiehr@u.washington.edu

Peggy A. Hannon
University of Washington

Barbara Pizacani
Multnomah Co Health Department

Mark Forehand
University of Washington

Jeffrey Harris
University of Washington

See next page for additional authors

Authors
Paula Diehr, Peggy A. Hannon, Barbara Pizacani, Mark Forehand, Jeffrey Harris, Hendrika Meischke, Susan J. Curry, Diane P. Martin, and Marcia R. Weaver

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Paula Diehr, Ph.D.[1 2]
Peggy A. Hannon, Ph.D., MPH [2]
Barbara Pizacani, Ph.D.[4]
Mark Forehand, Ph.D. [3]
Jeffrey Harris, MD, MBA, MPH [2]
Hendrika Meischke, Ph.D. [2]
Susan J Curry, Ph.D.[5]
Diane P Martin, Ph.D.[2]
Marcia R Weaver, Ph.D.[2]

From the Departments of (1) Biostatistics, (2) Health Services of the School of Public Health, and (3) Marketing, Michael G. Foster School of Business, of the University of Washington, U.S.A.; (4) Program Design and Evaluation Services, Multnomah County Health Department and Oregon Public Health Division, U.S.A.; and (5) School of Public Health, University of Iowa, U.S.A.

Corresponding author: Dr, Diehr, Box 357232, University of Washington, Seattle, WA, 98195. Phone 206-543-1044. E-mail: pdiehr@u.washington.edu

Key words: social marketing, stages of change, public health, tobacco control intervention, multi-state life table, transition probability

Abstract 404 words. Short abstract, 95 words.
Paper 5561 words, 2 tables, 2 figures

Some of the material in this technical report will be published in the Journal of Health Education and Behavior, 2010.

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Abstract

Background: In the transtheoretical model of behavior change**,** "stages of change" are defined as Precontemplation (not even thinking about changing), Contemplation, Preparation, Action, and Maintenance (maintaining the behavior change). Marketing principles suggest that efforts should be targeted at persons most likely to "buy the product."

Objectives: To examine the effect of intervening at different stages in populations of smokers, with various numbers of people in each "stage of change." One type of intervention would increase by 10% the probability of a person moving to the next higher stage of change, such as from Precontemplation to Contemplation. The second type would decrease by 10% the probability of relapsing to the next lower stage, such as from Maintenance to Action, and also of changing from Never Smoker to Smoker. Nine hypothetical interventions were compared with the status quo, to determine which type of intervention would provide the most improvement in population smoking.

Methods: Three datasets were used to estimate the probability of moving among the stages of change for smoking. Those probabilities were used to create multi-state life tables, which yielded estimates of the expected number of years the population would spend in each stage of change starting at age 40. We estimated the effect of each hypothetical intervention, and compared the intervention effects. Several initial conditions, time horizons, and criteria for success were examined.

Results: A population of 40-year-olds in Precontemplation had a further life expectancy of 36 years, of which 26 would be spent in the Maintenance stage. In a population of former and current smokers, moving more persons from the Action to the Maintenance stage (a form of relapse prevention) decreased the number of years spent smoking more than the any other intervention. In a population of 40-year-olds that included Never Smokers, primary smoking prevention was the most effective. The results varied somewhat by the choice of criterion, the length of follow-up, the initial stage distribution, the data, and the sensitivity analyses.

Conclusions: In a population of 40-year-olds, smokers were likely to achieve Maintenance without an intervention. On the population basis, targeting quitters and never-smokers was more effective than targeting current smokers. This finding is supported by some principles of health marketing. Additional research should target younger ages as well as other health behaviors.

Using the Stages of Change Model to Choose an Optimal Health Marketing Target

1 Introduction

Because the budget for public health is limited, health agencies trying to modify population behavior must choose effective interventions. Insights from the disciplines of individual behavioral change and health marketing may be helpful in making these choices. Individual-level counseling is often based on the Stages of Change model, also known as the transtheoretical model.[1 2 3] The model defines five stages of change: Precontemplation, Contemplation, Preparation, Action, and Maintenance. (A sixth stage, Termination, is not addressed here). In these terms, the objective of a public health intervention is to improve the distribution of persons among the stages.

Social/health marketing uses marketing principles to change behaviors,[4 5 6] using tailored messages to target specific segments of the population. One recommended strategy is to target those most ready to change, which would seem to ignore the persons most in need of help (those in Precontemplation). We wondered whether the stages of change model would help to determine the optimal target population and type of intervention.

An earlier study compared hypothetical public health interventions by conceptualizing the public as being in 3 states: healthy, sick, or (over time) dead.[7] That study estimated the probabilities of transition among the three states and then examined the effect on future population health of modifying each of the transition probabilities. In most situations, a prevention approach of keeping more healthy people from getting sick was the most effective. However, if the public's tolerance for increasing the number of person-years of morbidity was high, an intervention to keep more sick persons from dying was more effective. And, if a large percentage of the initial population was sick, but the tolerance for additional years of morbidity was low, then making more of the sick people healthy was the most effective strategy.

Here, we used a similar approach, based on transitions among the stages of change for smoking (plus 2 additional stages for Never Smoker and Dead). We characterized the public according to the number of people in each stage of change, and estimated the effect of a hypothetical intervention that changed exactly one of the transition probabilities by a specified amount. We hypothesized that the best intervention would depend on the transition probabilities, the criterion for success, the initial distribution of the population, and the time horizon for evaluation. We used data from three published studies to estimate transition probabilities among stages, then calculated multi-state life tables, and finally compared the outcomes of the various hypothetical interventions. The goal of the paper is to determine which type of intervention will have the most effect on population smoking. A secondary goal is to understand whether some of the less intuitive recommendations of social/health marketing apply to the specific health problem of smoking.

2 Methods

2.1 Data

Three sources of data were used to estimate transition probabilities. The primary dataset came from the evaluation of the Henry J Kaiser Family Foundation Community Health Promotion Grant Program (CHPGP). [8] The evaluation interviewed 5553 adults from 11 western U.S. communities, by telephone, in up to 3 waves, 2 years apart, for a total of 9622 assessments of stage change. Telephone interviews were based in part on random-digit dialing, and in part on telemarketing lists. [9] Although there was an intervention, there was no evidence of effectiveness, and we have combined the treatment and control subjects for the current analysis. Age ranged from 16 to 100, with a mean of 52.

The survey included smokers and non-smokers, and several other health behaviors were also assessed. Unfortunately, only half of the sampled persons were successfully interviewed at wave 1, there was 40% attrition to wave 2, and a further 27% attrition to wave 3. Smokers were more likely than non-smokers to be lost to follow-up. [10] These features are addressed later on. Stages of change were operationalized (by PD) from the available data, as shown in Table 1. We also included a stage for Never Smokers, which allowed us to examine smoking prevention in the same context as other interventions. Note that Precontemplation and Contemplation had to be defined by behavior, rather than by intention to change. For this reason we included two additional datasets.

[Table 1 about here]

The second study, referred to here as the Martin study, followed 545 ever-smokers from Rhode Island and Texas who responded to a newspaper advertisement.[11] Their stages of change were assessed up to 5 times, at six month intervals. The definitions of the stages are in Table 1. Precontemplation and Contemplation were appropriately based on the person's intentions rather than on their actions. The Preparation stage was not assessed, and the amount of attrition was unknown. The third, the Pizacani study, included information on 544 current smokers, identified from a 1997 population-based telephone survey of adult Oregonians, who were re-interviewed after a median of 21 months. [12] The attrition rate was about 50%. Precontemplation and Contemplation were appropriately based on the person's intentions. Non-smokers at baseline (Action, Maintenance, Never) were not followed in the second survey wave. The Martin paper is the closest to the Prochaska definitions of the stages, except that there was no Preparation stage. Preparation is usually defined as intention to quit in the very near term, sometimes combined with taking concrete steps like setting a quit date.

Table 2 provides additional information about the three datasets, which differed in the number of waves, the time between waves, the definitions or stages of change, and the number of smokers at baseline. The baseline distribution of the stages is also shown.

[Table 2 about here]

2.2 Analysis

Data from the three studies were used to estimate transition probabilities among stages and, from them, multi-state life tables were constructed. Hypothetical interventions were created that improved each of the transition probabilities by 10%.

2.2.1 Transition Probabilities

A transition probability is the probability of moving from one stage to another stage in the next period. Age-specific probabilities were estimated from the three datasets. Because no dataset included information about death, we assumed that mortality rates differed by stage, as follows: the age-specific probability of death for persons in the Maintainance stage was set to the national age-specific estimate for men (e.g., the probability of death in two years is .00533 at age 40),[13] the probability for those in the Action stage was 1.5 times as high (.00800), the probability for current smokers was twice as high (.01067), and the probability for Never Smokers was half as high

(.00267 at age 40). More detail is given in Appendix 1, and examples of transition probabilities are given in the Results section.

2.2.2 Multi-state Life Tables

The transition probabilities for each study were used to create a multi-state life table. That is, for a particular initial population (specified by the number of people in each stage at age 40) the probabilities were used to project what the distribution would be 2 years later, 4 years later, and so on. In the same way that a standard life table calculates life expectancy, the multi-state life table calculates the expected number of years that a particular population will spend in each stage in the future. We considered a lifetime (60 year) horizon, from age 40 to 100, as well as 10-year and 4-year time horizons. We estimated trajectories for a population in which everyone was in a single stage at age 40 (e.g., all in the Action stage) as well as for a population distributed like the observed baseline data from each dataset.

2.2.3 Existing and Hypothetical Interventions

The stages of change can be useful in characterizing existing interventions. For example, prevention messages such as the American Legacy Foundation "Truth" ads focus primarily on decreasing the probability of transitioning from Never Smoker to smoker. [14] Programs that cover the cost of nicotine replacement drugs help smokers in the Action phase abstain long enough to reach Maintenance, thus increasing the probability of moving from Action to Maintenance. Smoking bans may increase the probability that current smokers transition from Preparation to Action. [12] Bans may also decrease the probability that maintainers relapse, and resulting changes in the social norms may cause further changes in the transition probabilities. Smoking cessation quitlines are another example of an intervention that may affect multiple stages. Smokers are expected to set a quit date with the quitline counselor, which increases the probability that they will move from Preparation to Action. The ongoing counseling after quitting should increase the probability of transitioning from Action to Maintenance.

The marketing literature suggests that one cannot address all of the stage transitions in a single message and should instead focus on one stage transition at a time. [15] [16] [17] For this reason, we restricted the current study to 9 simple hypothetical interventions, described in Table 3. Each intervention would "improve" one of the transition probabilities by 10% (an arbitrary choice). The interventions either increase by 10% the probability that a person would advance by one stage, or decrease by 10% the probability of regressing one stage. (Weaker interventions might be conducted with greater intensity than the stronger ones to achieve the specified 10% improvement).

[Table 3 about here]

For example, in the Martin dataset, the probability of moving from Precontemplation to Contemplation 6 months later was .326. To "improve" that probability by 10%, we increased Prob(Precontemplation➔Contemplation) by 10% (at age 40, from .3260 to .3586) and, to ensure that probabilities would still add to one, reduced Prob(Precontemplation➔Precontemplation) by the same amount (at age 40 from .5860 to .5534). A different hypothetical intervention reduced Prob (Maintenance 🡐Never Smoker) by 10%. The modified transition probabilities were used to calculate multi-state life tables, and the expected years spent in each stage were compared with those from the status quo and from the other interventions. Table 3 lists the hypothetical interventions that were evaluated. The status quo intervention used the unmodified probabilities. Only the CHPGP study could be used to examine intervention 9, and the Martin dataset had only 4 stages.

Note that some of the interventions are more complicated than they appear. For example, intervention 9 lowers the probability that Never Smokers will transition to the Maintenance stage. The only way that transition can occur is for a Never Smoker to start smoking and then to stop again, eventually ending up in Maintenance. Similarly persons can not move directly from the Maintenance to the Action stage, because they must first start to smoke again and then stop before moving to Action. Remaining in Action (as a short-term quitter) requires relapsing and then quitting again. Interventions 1-5 all influence movements among stages of current smokers toward Maintenance, and can be thought of generally as smoking cessation interventions. Interventions 6-8 deal with quitters, and so are variants of relapse prevention. Intervention 9 is smoking prevention.

2.3 Comparison of hypothetical interventions

We next consider design features that might affect the choice of intervention.

2.3.1 Measures of Success

The primary outcome was the expected number of person-years not smoking. For the Martin and Pizacani data non-smokers are persons in the Maintenance stage, and for the CHPGP data, non-smokers may include both the Maintenance and the Never Smoker stages. There were two secondary outcomes. One was life expectancy from ages 40 to 100. The next, "partial credit sum" gives credit for years spent in all stages, but gives more credit for being in the more desirable stages, as follows: Outcome = 1 point for each year in Precontemplation+ 2 points for each year in Contemplation + …. + 5 points for each year in Maintenance or as a Never Smoker. (This choice of weights was arbitrary). This type of outcome is often used in evaluations with short follow-up where the most that can be expected is that the intervention move persons to higher stages, not necessarily that they achieve Maintenance.

2.3.2 Time Horizons

Three different time horizons were considered: lifetime (from age 40-100), 10-year (from age 40-50) and 4-year (from age 40-44).

2.3.3 Initial Conditions

For each dataset we first considered hypothetical populations in which every person was in the same stage at age 40 (e.g., an initial population of 100,000 Precontemplators, or 100,000 Never Smokers). In addition, we examined an initial population distributed proportionally to the actual baseline data, shown in Table 2.

2.3.4 Sensitivity Analyses

We modified some of the key probabilities, as explained in the Results section, to determine how sensitive the findings were to bias in the estimated transition probabilities. These key probabilities include the probability of remaining in Precontemplation, of remaining in Maintenance, of moving from Never to Maintenance, and of dying.

3 Results

3.1 Transition Probabilities

Table 4a shows the raw transition probabilities for the 9622 available transition pairs (two measures for the same person one wave apart) in the CHPGP data, for persons aged 18-100. For example, the 993 persons in Precontemplation had about a 63% chance of remaining in Precontemplation 2 years later, but a 16% chance of moving to Contemplation and a 6% chance of moving to Maintenance. Note that because of the long time between survey waves (2 years), every transition was logically possible except for going from smoker to “Never Smoker”. Persons in the Precontemplation, Maintenance, or Never Smoker stages were most likely to be in that same stage at the next wave (2 years later) , but those in Contemplation, Preparation, or Action were more likely to have moved to a different stage. This may be in part a function of how the stages were defined.

[Table 4 about here]

The Martin transition probabilities are in Table 4b. Here, some transitions are logically impossible (the probability is zero). For example, a smoker cannot move from Precontemplation to Maintenance in a single step because a person cannot have abstained for more than 6 months within 6 months of having been a smoker. Note also that persons could move more than a single stage in six months; for example, transition from Precontemplation to Action occurred 11% of the time. Table 4c shows the first 3 rows of the Pizacani 2-year transition probabilities. Because non-smokers were not followed after baseline, the missing rows for Action and Maintenance were taken from the CHPGP data for the life table calculations.

3.2 Multi-state Life Tables

We used smoothed age-specific CHPGP transition probabilities to estimate the trajectory of hypothetical populations of size 100,000 where all were in a single stage at age 40. For example, Figure 1 shows the estimated distribution over time (age) of a hypothetical population of 100,000 persons who started out in Precontemplation (bars with vertical stripes) at age 40. Note that by about age 50, more than half have moved to Maintenance (clear bars), and that number increases until about age 62 after which it declines as more persons die. Thus, even with this unfavorable initial distribution, the great majority of person-years are projected to be spent in Maintenance. The area under the lowest curve is the expected number of years in Maintenance, 26.0 years. Life expectancy (the area under the highest curve) is 35.6 years (data not shown). For a 4-year time horizon, we summed only the person-years from age 40-44, and summed from 40-50 for the 10-year horizon.

[Figure 1 about here]

We also used the CHPGP baseline population (Table 2), which includes Never Smokers, as the initial population. Life expectancy was 38.1 years from age 40. Of that, the population would average 23.2 years in Maintenance, and 11.8 years in Never Smoker, for a total of 35.0 years not smoking. For the Martin probabilities and baseline distribution, life expectancy was 36.3 years after age 40, with 23.9 years spent in Maintenance. For the Pizacani data, the status quo life expectancy was 35.4 years after age 40, with 27.5 years in Maintenance. These life expectancies are smaller than the life expectancies for CHPGP, in part because the baseline populations include no Never Smokers.

3.3 Comparison of Interventions

Table 5 shows the number of the intervention that maximized the number of person-years spent as a non-smoker (Never Smoker or Maintenance). Columns represent different datasets and time horizons, while rows represent different initial populations at age 40. The first 6 comparisons are for populations that include only current and former smokers, and the last 2 include Never Smokers. For example, for an initial population in which everyone was in Precontemplation and the evaluation horizon was 60 years, intervention #7 (Action→Maintenance) had the best outcome (more years not smoking) for all 3 datasets (columns 1, 4, and 7). Footnotes indicate cells where results for the other outcome measures or from the sensitivity analyses gave a different result from that in the table, as explained below.

3.3.1 Results of Primary Analysis

The primary results are in column 1 of Table 5, for CHPGP data with a 60-year follow-up and the expected number of years not smoking (Maintenance or Never Smoker) as the outcome. Intervention #7 was best for all of the initial populations that were restricted to current and former smokers (lines 1-6), and #9 was best when Never Smokers were included in the population (lines 7 and 8). The intervention effects were not large. For example, the best CHPGP intervention for the baseline population increased the average number of days not smoking by 58 days per person (data not shown).

[Table 5 about here]

3.3.2 Other Datasets.

The Martin and Pizacani datasets were too small to permit estimation of age-specific transition probabilities, and were missing important stages. They did, however, have more appropriate definitions of the Precontemplation and Contemplation stages than the CHPGP data. The close agreement of column 1 with columns 4 and 7 suggests that the findings are not sensitive to the exact definitions of the stages, or to the time between waves.

3.3.3 Shorter Time Horizons

Results from the shorter time horizons generally supported those for the 60-year horizon. There was a difference only for the Maintenance population (intervention #8 was chosen for the shorter term) and for the Baseline population that included Never Smokers (#7 was chosen for the shorter term). These discrepancies denote situations in which performing a short-term evaluation could result in selecting the "wrong" intervention; that is, an intervention that did not maximize the long-term expected number of years spent not smoking.

3.3.4 Other outcome criteria

In the primary analysis (column 1), the use of different outcome criteria made no difference. There were occasionally some effects in the other columns (footnotes A-E), which suggests that investigators who compare short-term interventions using the partial credit sum or survival outcome criterion could choose the wrong intervention as defined above.

3.3.5 Sensitivity Analyses using the CHPGP data

3.3.5.1 Modifying the probabilities

It is likely that participants in the three studies were positively selected, because they were volunteers, and because smokers were less likely to provide follow-up information.[#10] To examine this possibility further, we re-weighted the CHPGP data, giving most persons a weight of 1, but giving the persons who were in Precontemplation in 2 consecutive waves (who made no change) a weight of 5. The resulting probability of remaining in Precontemplation increased from about .6 to about .8 to .9, depending on age. The results of this extreme re-weighting is shown by footnotes F, G, and H in Table

5 (evaluated for CHPGP only). Interventions #1, #2, and #8 were sometimes chosen under the revised probabilities.

A second sensitivity analysis weighted all the persons who remained in Maintenance by one-fifth, lowering the estimated probability of remaining in Maintenance. Table 5, footnote I, indicates that in only one case did this make a difference, and there was no difference in Column 1. The rate of smoking initiation in the CHPGP was nearly 5%, and was fairly similar at all ages (data not shown). This was higher than expected, since there is indirect evidence that most persons begin to smoke at much younger ages. [18] (See Appendix 2). For this reason, the third sensitivity analysis weighted persons who transitioned from Never to Maintenance by one fifth, to make smoking initiation less likely. As footnote J shows, there were changes in a few outcomes, but none in Column 1. The primary results were thus sensitive to large biases in the estimated probability of remaining in Precontemplation, but not to biases in the other two probabilities.

3.3.5.2 Sensitivity to mortality assumptions

To determine whether our strong assumptions about mortality affected the results, we varied the assumptions in two ways (for CHPGP only). We first assumed that the probability of death for Never Smokers was 80% of those in Maintenance (rather than the 50% used in the standard model), similar to the relative risk determined elsewhere for middle-aged women.[19] This modification had no effect on the findings. Second, we assigned the identical age-specific death rate to every stage. Footnote K in column 1 shows that intervention #7 would be chosen instead of #9 under this extreme version of the mortality probabilities.

4 Summary and Discussion

4.1 Summary

This paper examined hypothetical interventions that modified the probability of moving from one stage of change to another. We estimated the effect of 9 hypothetical interventions on 8 initial populations of 40-year-olds and compared the outcomes with the status quo. For comparison, we used three time horizons and three datasets. Sensitivity analyses were conducted for different outcome measures and transition probabilities.

The primary analysis used the CHPGP data, with 60-year follow-up, and the number of years spent in Maintenance or Never Smoker as the outcome (the first column in Table 5). Intervention #7 (Action➔Maintenance) was the best for all of the populations of current and former smokers, but intervention #9 (Maintenance🡐Never) was better in populations that included Never Smokers. The results are generally consistent with those for the Martin and Pizacani datasets. For this reason, we believe that the poor operationalization of the Precontemplation and Contemplation stages in the CHPGP data, and the varying time between survey waves, were not a problem.

The shorter time horizons and different outcome measures did not affect the primary analysis, but occasionally changed the results in other columns. These cases indicate study designs that may give the "wrong" answer, and experimentalists should avoid them if possible.

The sensitivity analyses for the transition probabilities (footnotes F through L) did sometimes change the results in column 1. Notably, if the population of interest is primarily in the Preparation stage or lower and the probability that a person stays in

Precontemplation is much higher than observed here, interventions #1 (Precontemplation→Contemplation) or #2 (Precontemplation ← Contemplation) might be preferred. (The probability of remaining in Precontemplation was even lower in the other two datasets than in CHPGP, suggesting that underestimating this probability may not be a large concern). Intervention #8 (Action← Maintenance) might be better than #7 (Action → Maintenance) for a population all in Maintenance, which would then agree with the other two datasets. The results for a general population that includes Never Smokers might change from #9 (Maintenance←Never) to #7 if the mortality assumptions were extremely incorrect, although we think it unlikely that all stages have the same mortality.

The surprisingly good performance of intervention #7 (Action→ Maintenance) in populations that initially had no persons in the Action stage can be better understood by considering Figure 1. Intervention #7 can not have any effect at age 40, because there are no persons in Action. This is why shorter-term evaluations might not find intervention #7 to be the best. However, there are some persons in Action every year after that, and about half of them next move to Maintenance (see Table 4), which they are unlikely to leave (per Table 4, they have a 95% chance of remaining in Maintenance 2 years later). This non-intuitive finding demonstrates the importance of actually examining these transition probabilities.

4.2 Implications for Public Health

A health agency may wish to improve the health of the public in the area of smoking. If only one type of intervention can be afforded, column 1 of Table 5 suggests that the best type of intervention is prevention (#9) if the population of interest includes a substantial number of Never Smokers, and a type of relapse prevention (#7) if the population includes only current and former smokers. Even if the agency is interested only in current Precontemplators, intervention #7 would still be preferred unless the transition probabilities used here are grossly inappropriate for the agency's catchment area. If that is believed to be the case, the agency may need to conduct a survey to estimate the correct transition probabilities.

The relatively poor performance of the smoking cessation interventions (#1-5) may seem surprising, since for an individual in Precontemplation the first necessary step is to move from that stage. However, the 2005 National Health Interview Survey data [20] show that at least half of all smokers make one or more serious quit attempts in a given year, which agrees with our transition data. Smokers thus tend to try to quit, even without an additional intervention, but they often fail to maintain that cessation,[21] and interventions that help them do so are more effective. This finding illustrates the difference between the perspective of an individual smoker and the public health perspective.

The choice of an actual intervention is more difficult, because existing interventions do not often map neatly into the stages of change and, as mentioned earlier, may address more than one transition at a time. The study's findings suggest concentrating on existing interventions that focus mainly on prevention or on relapse prevention.

There is a further implication for experimentalists who wish to compare the effects of several existing interventions. Such evaluations would necessarily be of short duration, and power considerations may require using something like the partial credit sum as the outcome measure. The results in Table 5 suggest that in some cases the use of the short time horizon or the partial credit sum would have selected an intervention that was not best in terms of long-term smoking minimization. Experimentalists should be aware of that possibility.

4.3 Implications for Social/Health Marketing

As the number of evidence-based interventions increase and attention turns to dissemination and implementation science, public health professionals need models to guide their work in marketing the successful interventions.[22] Many of the familiar concepts of the transtheoretical model lend themselves to the concepts of marketing to targeted audiences.

One principle of social/health marketing is to "target markets most ready for action," which suggests an intervention involving the Action stage. [4] Although this approach would seem to ignore persons in earlier stages of change, the Action➔Maintenance intervention (#7) was usually found to be best for that group as well.

Another marketing principle is "customer relationship management" (CRM), which directs attention not just to satisfying customers, but also encouraging their loyalty. It is normally more expensive to acquire a new customer than it is to retain one (or in this case, to successfully achieve smoking cessation than to maintain a cessation). Successful firms often dedicate a great deal of attention to addressing the needs and encouraging the loyalty of their current customers. [23] In the smoking arena, this insight would address the cost of losing otherwise committed non-smokers back into an earlier stage of change. The resources required to re-engage these individuals will likely be greater than the resources required to transition them from Action to Maintenance. CRM considerations would seem to suggest that a relapse-prevention intervention would be best, and #7 is in fact a type of relapse prevention, among recent quitters. Our findings suggest that improving the loyalty of new customers is more important than improving the loyalty of long-term customers. Marketing research also suggests particular efforts to increase the loyalty of "brand-switchers" (persons who have tried another brand but are currently using our brand), who may be analogous to the recent quitters in the Action stage.

The key metric that marketers use in CRM is "customer lifetime value," defined as the present value of the profit stream that the company would have realized if the customer had not defected prematurely. [4] In the smoking context, this "profit" could be considered as the reduced costs to employers, insurers, and society at large that come from quitters remaining as non-smokers. This quantity should be related to the increase in the expected number of years spent as non-smokers, one of the outcome measures used here. These marketing recommendations agreed substantially with the recommendations based on stages of change transition model.

The earlier paper found strong support for prevention interventions, but this was modified somewhat by society's preferences for the various stages. [7] This is similar to the findings here, where relapse and primary prevention are favored if the objective is to maximize years spent in Maintenance, but where different interventions are sometimes chosen if the partial credit objective function is used.

4.4 Limitations

Each of the datasets had some weaknesses, such as poor operationalization of stages, small sample size, missing stages, and lack of mortality data. However, the results for the three datasets agreed substantially, and sensitivity analyses suggested that results were not very sensitive to biases in the estimated probabilities.

We had data to predict results only for populations aged 40 at baseline, where smoking initiation is believed to be rare. Similar analyses of younger persons are of particular interest. If their smoking initiation rates are higher, results for a prevention intervention (#9) should be even more favorable. Separate analyses by gender may also be of interest.

The hypothetical interventions improved a single transition probability, and not every transition probability was considered. Some interventions, such as quit lines and indoor smoking bans, probably affect more than one transition, which was not addressed here. Interventions might also be applied sequentially, such as using intervention #1 followed by intervention #7, but we did not evaluate combined interventions.
The multi-state life table calculations require population estimates of the average transition probability for each age and stage, and do not require that the one-state Markov properties hold if the population is at equilibrium.[24] However, without those properties, questions such as the best intervention for persons who have been in a particular stage for several years in a row or the expected number of cycles before leaving the Precontemplation stage can not be addressed in general. In addition, as more people move to Maintenance, social norms may change, and the probability of stage transitions may also change. We kept the amount of improvement small in this study, to avoid that possibility

We did not discount the number of years in the Never Smoker or Maintenance stages, but the use of shorter time horizons is conceptually similar to discounting. This paper did not address the cost of an intervention, because the interventions are hypothetical. If intervention #7 or #9 is substantially more expensive than alternatives, it might not be cost-effective. The work presented here has assumed that costs were equal for each hypothetical intervention, but that need not be the case. Appendix 3 discusses the cost of interventions further.

4.5 Conclusions

We conclude that for a general population of persons over age 40**,** persons in Precontemplation are likely to reach the Maintenance stage even under the status quo. Public health interventions that emphasizes relapse prevention or primary prevention seemed to be more effective than smoking cessation programs (defined here as interventions 1-5) in increasing the expected number of years that a population does not smoke. Some of the concepts of the transtheoretical model can be applied to marketing public health interventions to targeted audiences. Future research should continue to explore applying these concepts to positioning public health products and services. Similar research is needed in younger populations, and for other health behaviors.

Appendix 1

Transition Probabilities

Because the CHPGP dataset was large, we were able to estimate age-specific transition probabilities. The raw probabilities were then smoothed over age by linear discriminant analysis, as a function of age, log age, and log (101-age). Probabilities were estimated for ages 18-100 but, due to sparseness of data at younger ages, we used only the fitted probabilities after age 40 for this analysis. The Martin paper included four 6-month transition matrices, estimated from the different waves of data. Here, we averaged the four transition matrices, and assumed that the transition probabilities among the living stages were the same at all ages. We had access to the raw Pizacani data but, because the sample size was small, we calculated a single transition matrix and assumed that the probabilities among living stages were the same at all ages. Transition data were available only for persons who were smoking at baseline. Transition probabilities for quitters (Action and Maintenance) were taken from the CHPGP data for the life table calculations. This seemed acceptable because the Pizacani data were included primarily to strengthen the findings for the Precontemplation and Contemplation stages.

The method of multi-state life tables requires the probability of transitioning to death, which was not available for any dataset. We made the arbitrary assumption that the age-specific probability of death for persons in the Maintainance stage was equal to the national estimate for men (e.g., the probability of death in two years = .00533 at age 40),[25] that the probability for those in the Action stage was 1.5 times as high (.00800), that the probability for current smokers was twice as high (.01067), and that the probability for Never Smokers was half as high (.00267 at age 40). We then multiplied the observed transition probabilities among stages at a particular age by (1 – the probability of death at that age and stage), so that the resulting transition probabilities would add to 1.0. For the Pizacani data, we also used 2-year mortality data, corresponding approximately to the 21 months between survey waves. For the Martin data, for convenience, we assumed that the time between surveys waves was 1 year rather than the actual 6 months, so that standard life table data could be used. In a sensitivity analysis, reported elsewhere, the mortality assumptions made little difference.

Appendix 2

Bias in the rate of smoking initiation

The rate of smoking initiation in the CHPGP was nearly 5%, and was fairly similar at all ages (data not shown). This was higher than expected, since there is indirect evidence that most persons begin to smoke at much younger ages. [26] We have not located other data on smoking initiation at older ages for comparison, and it is possible that this rate is accurate. It is also likely that some persons who had smoked about 100 cigarettes in their lifetime might have answered "no" to this question at baseline and "yes" at a later time, giving the impression of smoking initiation. This possibility is consistent with most of these persons being in the Maintenance stage at follow-up. In unpublished data from the Cardiovascular Health Study (PD, personal communication) 5% of persons who were Never Smokers in one year claimed, one year later, to have quit smoking more than one year ago. This logical impossibility suggests that measurement error is a strong possibility. Only one dataset permitted us to examine smoking initiation interventions. Additional data would be valuable. However, in the sensitivity analysis that decreased the initiation rate to 1%, the results did not change very much.

Appendix 3

Relative effectiveness of two intervention types

Let α be the amount of improvement in the transition probabilities (α =.10 in our examples) and let Δ be the effectiveness of the intervention – the difference between the years not smoking under the intervention and the status quo. Diehr et al. noted in another study that, if α is small, Δ is approximately proportional to α, or $\Delta_i = K_i \alpha_i$, where i refers to the intervention. [#7] Alternatively, $K_i = \Delta_i / \alpha_i$, or $\alpha_i = \Delta_i / K_i$. For example, if everyone was in Precontemplation at baseline, and a lifetime time horizon was used, the status quo is 26.04 years spent not smoking, intervention 1 yields 26.06 years (Δ_1=.02), and intervention #7 yields 26.18 years (Δ_7=.14). Since all experiments use α = .10, K_1 = .02/.10 = .20 and K_7 = .14/.10 = 1.4. To determine what amount of improvement using intervention #7 (α_7^*) is equivalent to 10% improvement using intervention 1, we need to solve for $\alpha_7^* = \Delta_1 / K_7 = 0.02 / 1.4 = .014$. That is, intervention #7 with an improvement of .014 is equivalent to intervention 1 with an improvement of 0.10. Put another way, intervention #7 is K_7 / K_2 = 7 times as strong as intervention 1.

The effect of actual interventions is likely related to their breadth and their intensity. By varying those factors, it may be likely to obtain an intervention, or a package of interventions, with the desired level of α. If the cost of an intervention is proportional to α, further generalizations may be made about cost effectiveness. In particular, using intervention #1 would cost 7 times as much as using intervention #7 to achieve a particular effect. If, however, costs were proportional to the amount of absolute change in the transition probability, $C_k \sim p_k \alpha_k$, then (using the numbers from Table 4a) the cost of intervention 1 is proportional to .159*.10=.0159, while the cost of intervention 7 is proportional to .594*.014=.008316. The ratio of costs is thus .0159/.008316 = 1.91, or intervention 1 costs about twice as much as intervention 7 to achieve the same effect. It is not known which of these costs models would be more appropriate. Additional discussion of the relative costs of hypothetical interventions can be found elsewhere.[7]

Table 1
Operational Definition of Stages in 3 Datasets

Stage	CHPGP	Martin	Pizacani
Time between waves	2 yrs	6 months	21 months
Stage:			
Precontemplation	No quit attempts in past year	No plans to quit in next 6 months	Not thinking of quitting
Contemplation	1-2 quit attempts in past year	Serious plans to quit in next 6 months	Thinking of quitting in next 6 months
Preparation	3+ quit attempts in past year	n/a	Thinking of quitting in next 30 days and at least one quit attempt in previous year
Action	Abstained for < 1 year	Abstained for < 6 months	Abstained for < 90 days
Maintenance	Abstained for > 1 year	Abstained for > 6 months	Abstained for > 90 days
Never Smoker	Smoked < 100 cigarettes in lifetime	n/a	Smoked < 100 cigarettes in lifetime
(Dead)	(Dead)	(Dead)	(Dead)

Table 2
Descriptive Statistics for 3 Datasets

	Dataset		
	CHPGP	**Martin**	**Pizacani**
1st Survey Year (approx)	1991	1996	2004
Number of survey waves	3	5	2
Time between waves	2 yrs	6 months	21 months
Loss to f/u (wave 1-2)	40%		50%
Mean Age	52	40	45
% male	41	32	50
# of Persons	5553	545	565
# of transitions	9622		565
Baseline Distribution:			
Precontemplation	.118	.143	.169
Contemplation	.059	.446	.192
Preparation	.034		.091
Action	.031	.147	.006 *
Maintenance	.247	.264	.213 *
Never Smoker	.511		.328 *
			* Not tracked

Table 3

Hypothetical Interventions for 3 Datasets

		Dataset		
		CHPGP	Martin	Pizacani
Intervention Number	Transition Probability to be improved in the hypothetical intervention: *			
0	Status Quo	X	X	X
1	Precontemplation➔Contemplation	X	X	X
2	Precontemplation🡐 Contemplation	X	X	X
3	Contemplation➔Preparation	X		X
4	Contemplation🡐Preparation	X		X
5	Preparation➔Action	X		X
6	Preparation🡐Action	X		X
7	Action➔Maintenance	X	X	X
8	Action🡐Maintenance	X	X	X
9	Maintenance 🡐 Never	X		
5a	Contemplation➔Action		X	
6a	Contemplation🡐Action		X	

*** The hypothetical intervention increases the probability of the "➔" transitions by 10% or decreases the probability of the "🡐" transitions by 10%.**

Table 4
Transition Probabilities (without mortality)

4a- CHPGP (raw)

		Time 2						N of Transitions
		Pre	Cont	Prep	Action	Maint	Never	
Time 1	Pre *	0.632	0.159	0.049	0.097	0.062	0.000	993
	Cont	0.369	0.291	0.120	0.110	0.110	0.000	426
	Prep	0.240	0.244	0.260	0.120	0.136	0.000	242
	Action	0.080	0.124	0.060	0.143	0.594	0.000	251
	Maint	0.008	0.010	0.012	0.022	0.949	0.000	2597
	Never	0.001	0.001	0.002	0.004	0.038	0.954	5113
	Total							9622

4b- Martin (fitted)

		Time 2						
		Pre	Cont		Action	Maint	Never	N of Persons
Time 1	Pre	0.57	0.33		0.11	0.00	0.000	78
	Cont	0.13	0.72		0.11	0.04	0.000	243
	Action	0.00	0.33		0.21	0.45	0.000	80
	Maint	0.00	0.00		0.05	0.95	0.000	144
	Total							545

4c- Pizacani (raw)

		Time 2						N of persons/ transitions
		Pre	Cont	Prep	Action	Maint	Never	
Time 1	Pre	0.461	0.284	0.062	0.011	0.183	0.000	211
	Cont	0.129	0.476	0.218	0.022	0.154	0.000	223
	Prep	0.202	0.264	0.233	0.138	0.163	0.000	110
	Total							544

* Pre is Precontemplation; Cont is Contemplation; Prep is Preparation; Maint is Maintenance; Never is Never Smoker.

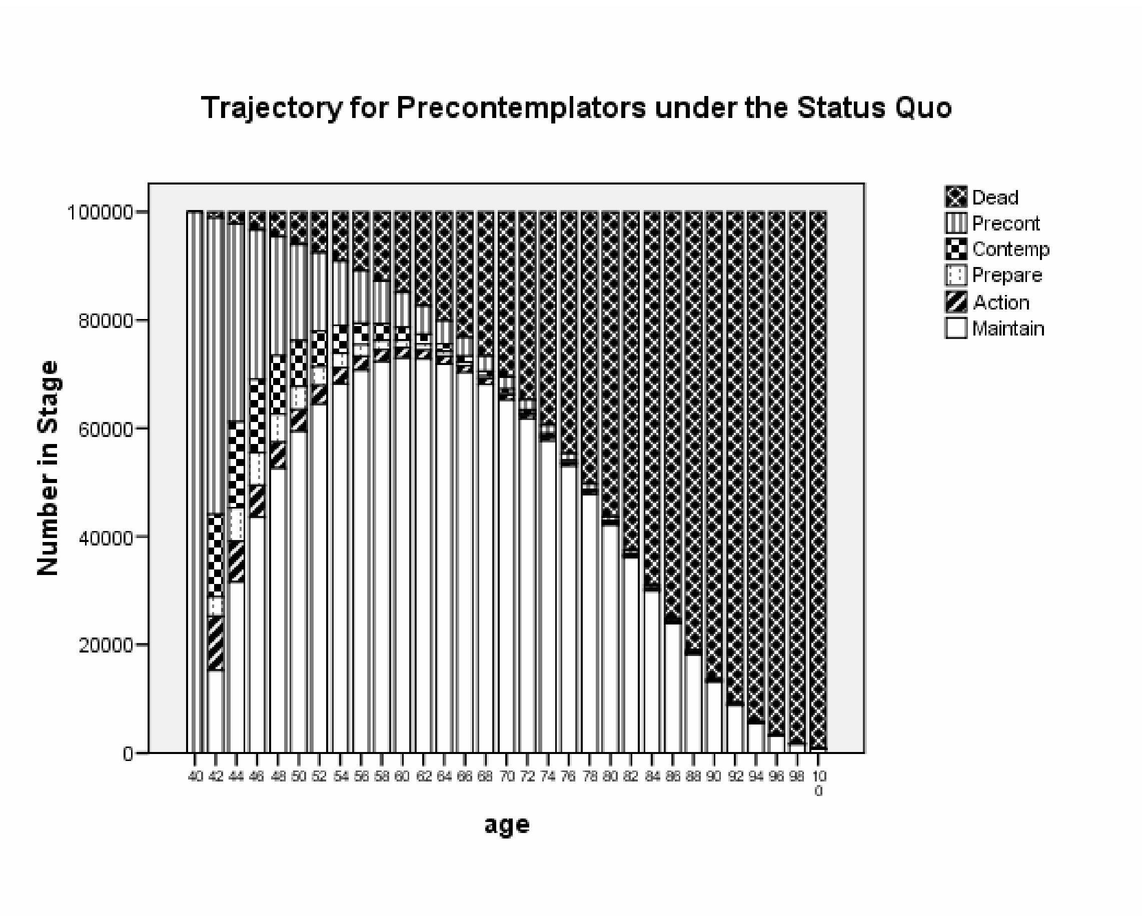
Table 5
Number of the intervention that gives the most person-years not smoking (Maintenance + Never) in various situations

Data	**CHPGP**			**Martin**			**Pizacani**		
Column	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Time Horizon (yrs)	**60**	**10**	**4**	**60**	**10**	**4**	**60**	**10**	**4**
Initial Distribution at age 40:									
1 Precontemplation	**7** [F]	**7**	**7** [D]	**7**	**7** [A]	**7**	**7**	**7** [C]	**7** [C]
2 Contemplation	**7** [G]	**7** [C G]	**7** [C G]	**7**	**5a**	**6a,7** [B]	**7**	**7** [C]	**7** [C]
3 Preparation	**7** [G]	**7** [C]	**7** [C]				**7** [C]	**7** [C]	**7** [C]
4 Action	**7**	**7**	**7**	**7**	**7**	**7**	**7**	**7**	**7** [D]
5 Maintenance	**7** [H]	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**8**
6 Baseline *	**7**	**7**	**7** [D I L]	**7** [E]	**7** [C]	**7** [C D]	**7**	**7** [C]	**7** [C]
+Never Smokers									
7 Never Smoker	**9**	**9** [J]	**9** [J]						
8 Baseline	**9** [K]	**7**	**7** [D I]						

*** The distribution among stages is proportional to the baseline distribution (Table 2). Only CHPGP included Never Smokers.**

Superscripts denote best intervention when different from the tabled results:
Other outcomes:
Partial credit sum outcome: A= intervention 1, B=2, C=5, D=6;
Survival outcome (60 yrs horizon only), E=8;
Sensitivity analysis (evaluated for CHPGP only):
5 times as many persons stay in Precontemplation next wave, F=1, G=2, H=8;
One-fifth as many persons stay in Maintenance next wave, I=8
One-fifth as many persons move from Never to Maintenance, J = 7
Mortality in Never Smokers only 80% of mortality in Maintainers (no differences)
Mortality is the same in all stages, K = 7, L = 6

Figure 1
Trajectory of a Population Initially in Precontemplation
(CHPGP transition probabilities)



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