An Expert System Intervention for Smoking Cessation

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Reference:

Note:
The published version had an error in Table 1 and the associated text. That is corrected in this version.

Abstract

The Pathways to Change system (PTC) is an Expert System intervention for smoking cessation. Assessments are performed either by mail or by a telephone interview and each smoker receives a 3-4 page report that provides individualized recommendations matched to the individual’s needs and readiness-to-change. The Transtheoretical Model of Change provides the theoretical basis for the expert system. Four different studies have demonstrated the efficacy of this intervention in a general population, with cessation rates of 22 to 26%. Furthermore, the difference between the groups was larger at each follow-up assessment point, indicating that the effects of the treatment increased long after the end of treatment. The studies involved two proactively recruited samples, demonstrating that a large proportion (85.3% and 82.5%) of the population of smokers could be successfully recruited into a smoking cessation program. Expert system interventions have the potential to have an extremely high impact on a total population of smokers.

1. Introduction

Of the people alive in the world today, 500,000,000 are predicted to die from the use of tobacco with an average loss of ten years of life. Consequently, five billion years of human life will be lost to one behavior. Even a modest breakthrough in developing an intervention with greater impact on populations of smokers could prevent millions of premature deaths and billions of lost years of life. This paper describes a computer-based expert system intervention that has the potential to increase our impact on a population of smokers.
Clinic-based interventions have been known to produce the largest amount of abstinence at long-term follow-up. Smoking cessation clinics, for example, typically result in 25 to 30% abstinence at twelve-month follow-ups. This is the case even when behavior change programs include nicotine replacement therapies such as nicotine gum (an average of 28% abstinence) or the patch (an average of 28% abstinence). While such clinical interventions produce the highest abstinence rates, they also produce the lowest participation rates. State of the science cessation clinics offered for free by HMO’s typically result in about one percent participation of eligible smokers and nicotine replacement therapy like the patch or gum is used by 1 to 3% of the population.

Home based programs, such as self-help manuals, can reach a larger percentage of an eligible population, typically 4 to 5%. But these programs result in lower abstinence rates (approximately 15%).

Practice based programs, such as brief physicians’ advice in a primary care setting, can reach much larger percentages of a population, typically 25 to 30%, but these programs result in even lower abstinence rates (about 7 to 10%).

Community based interventions, such as the Minnesota, Pawtucket, Stanford Heart Health, and COMMIT programs, have the potential to reach entire communities of smokers. Recent reports on these programs, however, indicate that they have produced no or little short-term or long-term increases in abstinence. Only a very small effect size such as 1% can be expected at best, but such programs have the potential to reach 70 to 80% of the population.

Public health policies, such as smoking bans at work or in public places, can reach entire populations of smokers. Such interventions have been shown to decrease the amount of cigarettes people smoke but have not yet been shown to increase quit rates.

The dilemma the field faces, then, is a choice of programs that produce the highest abstinence rates but the lowest participation rates or the highest participation rates but the lowest abstinence rates. The impact of a program equals its abstinence rate times its participation rate. In the past, programs were usually evaluated only by their abstinence rates. So a program that resulted in 30% abstinence was judged to be twice as effective as a program producing 15% abstinence. But a program producing 30% abstinence and 3% participation has only a .0090 impact on the population of smokers. A program producing 15% abstinence with 60% participation has a .0900 impact, which is a 10 time greater. What the field needs are interventions that can maximize participation rates without sacrificing abstinence rates.

One of the problems is that most interventions are designed for smokers who are ready to quit, but this is a small minority of the smokers. To increase participation rates, interventions must be matched to the characteristics of each individual. In effect, the intervention needs to have the individually tailored characteristics of a clinic program applied on a population level.

One solution to this challenge is take advantage of the potential provided by recent advances in information systems technology. This paper will focus on expert systems that can provide individualized and interactive interventions to whole populations of smokers in a cost-effective manner. An expert system intervention for smoking cessation called Pathways to Change will serve as an example of this type of technology. Three separate sections will describe aspects of this intervention. First, expert system interventions require a detailed theoretical model to provide the framework for the system. We will describe the Transtheoretical Model, which serves as the basis of the Pathways to Change program. Second, different methods of implementing expert system intervention can be developed. We will provide an overview of and a detailed description of the Pathways to Change
expert system. Third, the efficacy of interventions must be demonstrated empirically. We will briefly summarize the results from four clinical trials using this intervention. In the last section, we will discuss the implications of the empirical trials and discuss expert system interventions in the context of alternative approaches to smoking cessation.

2. Transtheoretical Model

The PTC expert system uses the Transtheoretical Model of Change\(^{25-27}\) as the theoretical basis for generating interventions. This model describes how people modify a problem behavior or acquire a positive behavior. The key organizing concept of the model is the Stages of Change concept. The model also includes a series of independent variables, the Processes of Change, and a series of outcome measures, including the target behaviors, the Decisional Balance scales, and the Temptation scales.

The five Stages of Change that characterize a patient’s readiness to participate in preventive care are Precontemplation, Contemplation, Preparation, Action, and Maintenance. In the Precontemplation stage, patients are not intending to take action in the foreseeable future. In the Contemplation stage, patients are intending to change their behavior within six months. In the Preparation stage, patients have recently made some changes in their behavior and plan to attempt take action again in the next month. Patients are in the Action stage for the first six months after quitting. Patients are in the Maintenance stage when they have taken action and maintained that change for six months or more. Regression occurs when patients revert to an earlier stage of change. Relapse is regression from Action or Maintenance to an earlier stage.

The Processes of Change are ten cognitive and behavior activities that facilitate change\(^{28}\). The cognitive processes are critical in the early stages and the behavioral processes are critical in the later changes.

The Decisional Balance scales\(^{29-30}\) involve weighting the Pros and Cons of continuing to smoke. In Precontemplation, the Pros of smoking far outweigh the Cons of smoking. In Contemplation, these two scales are more equal. In the advanced stages, the Cons outweigh the Pros. The Pros and the Cons capture some of the cognitive changes that are required for progress in the early stages of change.

The Situational Temptation scale\(^{31}\) involves an assessment of how tempted a smoker would be to smoke in a variety of situations. These include social situations, negative affect situations, and situations involving physical cravings. This scale is particularly sensitive to the changes that are involved in progress in the later stages and predicting relapse.

The Transtheoretical Model also involves a specification of the relationship between the Stages of Change and the dependent measures (Behavior, Pros, Cons, Situational Temptations), between the Stages of Change and the independent measures (Processes of Change), and between the dependent and independent measures. A complete description of this aspect of the model is beyond the scope of this paper and can be found elsewhere.\(^{32-36}\)

3. Pathways to Change Expert System

3.1. Overview

Expert systems interventions may be broadly classified as batch, interactive or distributed systems. A batch system derives its name from the era when mainframe computers were the dominant approach to computing. Materials were submitted to a central processor and, after a delay, the results were
returned. It is a distal system, involving no direct contact with the computer. For the smoking cessation expert system, information is gathered from the smoker either via mail or telephone and intervention materials are communicated, after a delay, in the same way. A batch system has the advantage that it requires only a single central computer and database to serve all smokers and that it can contact smokers at home. The disadvantage is that a complete assessment is required, followed by an interval before the intervention materials are communicated. The intervention materials are also limited to written materials. Figure 2 uses a communication model to illustrate some of the alternative methods of implementing a batch system.

Interactive versions of the PTC intervention have been developed and are being evaluated. Interactive systems have several clear advantages, including the use of different types of media for communication and tailoring the assessment and presentation to the needs of the individual. The interactive system also operates in real time, providing instant feedback. A limitation of the interactive system is that each smoker must be directly in contact with the computer. This requires a large number of computers. Since information is not gathered in a single central database, a method must be found to accumulate all the information quickly in a central database or restrict users to a single machine for all contacts.

The next generation of expert systems will involve distributed systems. These systems will take advantage of the advances in telecommunications and computer networks. In effect, distributed systems will combine the strengths of the batch and interactive approaches. A web-based system can be located on a single central computer but operate in an interactive environment. A single database can serve all users and feedback can be provided in real time. However, at the present time web-based systems are limited by the lack of access to the web by large segments of the population and the need for wide band communication channels to fully implement multi-media versions. Telecommunication approaches are more advanced because the telephone can be used to contact a large proportion of the

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**Figure 1. Alternative Communication and Feedback Channels for a Batch Expert System (from Velicer, Botelho, & Prochaska, 1998).**

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population at the present time. However, telecommunication approaches have the drawback of being limited to a single communication modality.

The PTC system described below is a batch system. This is the only PTC system for which multiple outcome studies have been performed and it is the easiest PTC system to implement in a wide variety of settings. Figure 1 illustrates the flow of this system. First, each individual smoker is assessed on the fourteen variables, plus the relevant behaviors. Second, the assessment is scored and data from any previous assessment is retrieved. Third, these scores are then compared to the relevant norms, and the decision rules determine which intervention materials are appropriate. The decision rules of the expert system are based on a series of multivariate statistical analysis were used to verify empirically the hypothesized relations between the variables of the model and outcome and determine the empirical cutoffs for the decision rules. For each stage, the goal of the analysis was to determine empirically how to optimize movement to the next stage. The decision rules also change with the stage of change. The intervention materials are then assembled into the feedback report.

![Flow Chart for the Expert System](from Velicer, Botelho, & Prochaska, 1998).

3.2. Assessment.

To generate an expert system report, the individual smoker is contacted and assessed on the Transtheoretical Model variables described above and the target behavior. In the batch system described here, assessing Stage of Change requires 2-5 items, depending on the stage, assessing the Processes of Change requires 20 items, assessing Situational Temptations requires 9 items, and assessing Decisional Balance requires 8 items. Not all variables are relevant for all stages. For example, the cognitive processes like Dramatic Relief (Emotional Arousal) and Consciousness Raising (Increasing Awareness) and the Decisional Balance scales would be the focus of interventions for smokers in the Precontemplation stage. The more behavioral processes like Stimulus Control (Re-engineering) and Counter Conditioning (Substituting) and the Temptation scales are more relevant for the later stages. The system described here assesses all the variables on each occasion but provides feedback only on the relevant subset. In contrast, an interactive system can assess only the most relevant variables rather than doing a complete assessment on each occasion.

3.3. Procedure.

Assessments are typically performed either by a telephone interview or by mailed questionnaires that can be optically scanned. The variables are scored and information is saved in a database. Three months later the person is assessed again and a second report is generated. Another assessment occurs three months later and a third report is generated. The individual reports are assembled from a large
number of available paragraphs on the basis of a complex set of decision rules. These rules are derived from prior longitudinal studies of how smokers change.

The first report is based on a comparison of the responses of the smoker to a large comparative sample of successful and unsuccessful quitters. This report relies only on normative comparisons. The norms differ by stages. The initial norms were derived from a naturalistic sample of smokers. Evaluation trials of the expert system provide updated norms at periodic intervals. The second and all subsequent reports compare the smoker to both the normative group and to their own previous responses and provide both ipsative, i.e., self-comparisons, and normative comparisons. The ipsative comparisons involve access to the database for the results of the previous contact. On the basis of these comparisons, a 3-4-page report is generated that makes individualized recommendations for change. The PTC system can generate almost 20,000 unique reports.


The 3 to 4 page feedback report is divided into four sections:
(a) Stage and Decisional Balance. This section contains a description of the subject’s current stage of change and their pros and cons of quitting. The feedback describes the interpretation of their stage, how their decisional balance compares to others and how they compare ipsatively with their last assessment.
(b) Processes of Change. This section provides feedback on the subject’s use of up to six change processes, how they compare normatively on each process with self-changers who were most successful in progressing to their next stage and how they compare ipsatively with their previous assessment.
(c) Tempting Situations. This section describes the tempting situations that are the most dangerous for the individual and provides feedback on how to successfully avoid or control those situations.
(d) Strategies. This section describes strategies for taking small steps to progress to the next stage. The strategy section is based only on stage. An example of a strategy for the contemplation stage is to delay the first cigarette of the day by an extra 30 minutes. The feedback report also refers participants to sections of the stage-matched self-help manuals.

4. Outcome Studies

4.1. Overview

Four studies based on three different samples have been performed to evaluate the efficacy of the PTC expert system for smoking cessation. In this paper, we will provide only a brief summary of some of the results of these studies. A more detailed description is available from the primary sources.

The following is a brief overview of the methodology common to all the studies. The outcome reported here is point prevalence abstinence. Other outcome measures, including two sustained abstinence measures, are reported in the original sources. All outcome measures produced a similar pattern of results. All the results reported here were statistically significant. All results reported here are based on a complete case analysis. Details of attrition are reported in the original sources and alternative methods of handling missing data had no impact on the conclusions about the effectiveness of the intervention. Eligibility requirements were very general and included a self-report that subjects were currently smoking, had no serious illness, were between the ages of 18 and 75, and were competent in English. No monetary compensation was provided to participants. The stage distributions for the last three studies matched that found in other representative samples. The first study involved a volunteer sample. Subjects were randomly assigned to condition and there were no differences between the groups at baseline in any of the studies with respect to either demographics or smoking history variables.
In each study, unless otherwise noted, the expert system intervention employed involved three contacts (Baseline, 3 months, and 6 months) as described in the previous section. In each study, the expert system intervention also included a series of stage-matched manuals and the expert system report referred the smoker to these manuals for additional materials. In each study, all groups were assessed at 6 month intervals.

4.2. Study 1.

The first study employed a reactively recruited sample of smokers. Smokers were recruited through newspaper announcements and advertisements. The study design was a 4 (group) X 4 (occasion) design. A comparison of the expert system intervention and related manuals to one of the best available sets of action-oriented self-help manuals for smoking cessation demonstrated that the expert system was more than twice as effective (25% point prevalence abstinence at 18 months compared to 11%). Figure 3 presents the point prevalence abstinence outcome data for two of the four groups involved in the study. The expert system condition is compared to the action-oriented manual group, the two groups relevant to this overview.

4.3. Study 2.

The second, third and fourth studies employed proactive recruitment in an attempt to provide an intervention to the entire population. Reactively recruited samples typically involve no more than 5% of the available population and tend to be disproportionally female, highly educated and in the later stages of change. In contrast, proactive procedures attempt to reach a larger proportion and a more representative sample of the at risk population. Proactively delivered expert system interventions can provide a unique combination of materials that are individualized to help to an entire population of smokers.

In the second study, a random-digit dial phone survey was employed to recruit a representative sample of smokers. Of the identified smokers, 82.5% were enrolled in the study and assigned to either an expert system intervention condition or an assessment only condition. The expert system intervention included the 3 reports and related manuals. The study design was a 2 (group) X 5 (occasion) design. At the 24 months follow-up, the point prevalence abstinence rate was 26% for the expert system intervention compared to 20% for the assessment only condition. The difference between the two groups was larger at each assessment point than the previous assessment point, indicating that the effects of the treatment continued long after the end of treatment (6 months). Figure 3 illustrates the results of this study.

4.4. Study 3.

The third and fourth studies shared the same sample. The entire population of a Health Maintenance Organization (HMO; a large defined group of patients who pre-pay a fee to an organized group of medical providers) was contacted to identify eligible smokers. 85% of the smokers agreed to participate in the study and were randomly assigned to treatment. In the first study, the study design was a 2 group (expert system vrs. manual only) by 4 contacts (1, 2, 3, or 6 contacts) by 4 occasions.
Figure 3. Outcome Results for Four Studies Evaluating Expert System Interventions
design which evaluated both the impact of interactive interventions versus non-interactive interventions and the impact of different numbers of contacts. At eighteen months, there was no clear dose response relationship. However, at each follow-up, the interactive (expert system plus manuals) intervention was more effective than the non-interactive (manual only) intervention. At the 18 months follow-up, the point prevalence abstinence rate was 22% for the four expert system intervention conditions compared to 16% for the four manual only conditions. Figure 3 illustrates this result for the comparison of expert system and manuals collapsed across the four levels of number of contacts.

4.5. Study 4.

In the fourth study, which shared the HMO sample with the third study, the standard expert system intervention condition and the assessment only condition were two of the four groups included. The expert system intervention included the 3 reports and related manuals. The overall study design was a 4 (group) X 4 (occasion) design. At the 18 months follow-up, the point prevalence abstinence rate was 23% for the expert system intervention compared to 17% for the assessment only condition. Figure 3 illustrates the results for these two groups.

5. Discussion

Several consistent findings emerge across the four empirical studies. First, the expert system intervention produces a point prevalence smoking cessation rate of 22 to 26% at the end of the study. Figure 4 summarizes the results for the expert system condition from the four studies. This rate is only slightly less than the rate achieved by intensive clinic-based intervention. This is impressive for two reasons. It was achieved with a total population in the last three studies and the intervention was of low intensity, delivered at home. Many smoking cessation interventions have been applied primarily to a self-selected subsample of smokers. This involves primarily smokers in the Preparation stage, i.e., those prepared to quit immediately. In a general USA population, this represents only 20% of the smokers. In European samples, the proportion of the sample in Preparation is likely to be even lower, i.e., closer to 10%. An intervention applied to a total population represents a much more difficult challenge. Likewise, clinic based intervention often involve the smoker coming to a central location for a series of meeting. This is costly in terms of time and resources and represents a barrier to many smokers, who prefer the delivery of services directly to the home.

A second important finding from the last three studies (involving only two samples) is the high recruitment and retention rates achieved. In the first sample, approximately 5000 smokers were identified through a random digit dialing procedure and 82.5% of the eligible smokers were proactively recruited. In the second sample, 4653 smokers of a managed care system were identified and 85.3% were proactively recruited. When an intervention is matched to the individual patient, such as the expert system intervention, it is possible to intervene with the vast majority of all individuals rather than the select few who are in the preparation stage. This greatly enhances the impact (efficacy X participation) of an intervention.

To calculate the size of the impact of the expert system intervention, we used the slightly lower sample size retained at six months, the point when intervention was completed. We estimated this to be 75% based on our two proactively recruited studies. Across the four studies, the efficacy of the expert system intervention was extremely consistent, averaging approximately 24% after 18 months. Based on these two estimates, we project the impact of the expert system intervention to be .180.
Table 1 presents a comparison with the impact of the other types of interventions described previously in this paper. The estimates provided for both the efficacy and impact are based on the information provided previously. They differ slightly but are similar to estimates found elsewhere. The expected impact of the expert system intervention is more than 60 times that of smoking clinics and more than 6 times as that of the next most effective, physician advice combined with nicotine replacement therapy. (The expert system intervention could also be combined with a pharmacological intervention, potentially increasing efficacy.)

A third major finding across the four studies involved the pattern of the intervention effects over time. The differences between the expert system intervention and the comparison group continued to diverge across the assessment occasions. It is common for the differences to be greatest at the end of treatment and then converge. In most of the conditions reported here, the intervention was completed after six months, but the treatment differences continued to diverge through the last assessment (either 18 or 24 months). One explanation is that an action criterion is being employed but the intervention is designed for smokers in all stages. Smokers in the early stages require more time to reach the action criterion compared to smokers in the later stages. Therefore, it is only at the extended follow-up that the early stage smokers reach the action criterion.

Table 1. Comparison of Impact for Different Interventions
Expert System for Smoking Cessation

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Efficacy</th>
<th>Participation</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoking Clinic</td>
<td>.30</td>
<td>.01</td>
<td>.0030</td>
</tr>
<tr>
<td>Pharmacological (NRT)</td>
<td>.30</td>
<td>.03</td>
<td>.0090</td>
</tr>
<tr>
<td>Self-help Manuals</td>
<td>.15</td>
<td>.05</td>
<td>.0075</td>
</tr>
<tr>
<td>Physician Advice + NRT</td>
<td>.10</td>
<td>.30</td>
<td>.0300</td>
</tr>
<tr>
<td>Community Inter.</td>
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<td>.80</td>
<td>.0080</td>
</tr>
<tr>
<td>Expert System</td>
<td>.24</td>
<td>.75</td>
<td>.1800</td>
</tr>
</tbody>
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Expert system interventions represent an emerging technology that can incorporate prevention into the health care information system. Expert systems have the potential to play the same role in behavioral medicine that pharmacological interventions play in biological medicine. They help to overcome a number of the barriers that prevent the adoption of behavioral programs for health promotion and disease prevention and possess a number of advantages. Some of the advantages include: Complete assessment. Computer based systems can conduct a comprehensive assessment, covering the whole range of behaviors. Integration into existing interventions. Expert systems can be modified to be synergistic with other interventions and to be complementary to the clinical encounter. A summary of the expert system report can be provided to the health care provider. Appropriate for a whole population. Expert system interventions are ideal for population based approaches. First, they can provide an efficient means of screening. Interactive systems can immediately branch to an in-depth assessment when a problem area exists. Second, expert systems can include a large array of interventions that can be matched to the individual. Expert systems can incorporate a wide variety of different intervention materials. Intervention approaches can range from motivational materials for patients in early stages and detailed advice and support for those patients who are in the later stages. As the patient progresses (or regresses) different intervention materials are available. Complete data. Expert systems provide an automated recording device so that even small amounts of progress can be detected and reinforced. These automated gathering of data provides an extensive empirical data base that can be used to both serve the patient and provide an evaluation of the effectiveness of the system. Cost. Prevention can be very expensive in term of the resources required to provide the services to all patients. Expert systems represent a potentially less costly alternative.

Expert system technology is still in its infancy and a number of other barriers exist that must be overcome before expert systems become widely available. However, the promise of this technology for modifying problem behaviors is outstanding. Advances in expert system technology will be driven both by advances in technology and by advances in our understanding of human behavior. Interactive versions of the PTC expert system interventions are already being tested at the University of Rhode Island and other research centers and distributed systems involving both the World Wide Web and telecommunications are being developed. The availability of a variety of different communication mediums (sound, pictures, graphics, and animation) as well as the ability to interact in real time has the potential to greatly increase the effectiveness of the interventions. As information systems technology improves and access to computers becomes more general, many of the current barriers to dissemination will disappear. Expert system interventions are being developed for a variety of other risk factors and parallel developments to those described for smoking cessation are occurring. Combining interventions in a multiple risk factor approach to improve health represents a promising alternative to the type of single risk factor interventions described here. Combining expert system technology with other interventions represents another promising avenue of investigation. The studies reported here have only investigated a very limited number of variations on the timing of the expert system contacts and
the number of expert system contacts. Both the optimal number and the optimal timing for intervention contacts may differ by stage. Research discoveries from basic research on how to modify human behavior can guide the improvement of future generations of expert systems. Technology-based interventions have the clear promise of facilitating disease prevention and health promotion in the general population.

Footnote
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References


