Tailoring Cardiovascular Risk Management Educational Interventions: A Synergy of SCORE Risk Assessment and Behaviour Change Model

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Quality and timely patient education can reduce cardiovascular risk. The PULSE (Personalization Using Linkages of SCORE and behaviour change readiness to web-based Education) project objectives are to generate and evaluate a web-based personalized educational intervention for the management of cardiovascular risk. The program is based on a patient profile generated by combining: (a) an electronic data capture template (DCT); (b) the Systematic COronary Risk Evaluation (SCORE) algorithm for ten-year risk assessment for fatal cardiovascular disease; and (c) a Stage determination model for behavioural change readiness. The DCT inherently contains a set of evidence-based parameters for patient description and disease evaluation. The SCORE estimation directs the selection of clinical guideline target values for risk factors. The patient's Stage of behaviour Change determines messages consistent with the individual's change processes, decisional balance, and self-efficacy. The interventions are designed to address both medical and psychosocial aspects of risk management and, as such, we combine staged lifestyle modification materials and non-staged messages based on Canadian clinical guidelines to motivate personal risk management. The personalization decision logic is represented in Medical Logic Modules implemented in Java. The PULSE educational process is initiated by a healthcare professional in a primary care setting. An intelligent interactive system generates the personally relevant educational materials and delivers them to the patient via the Web. An evaluation study will be conducted to determine whether web-based personalized educational strategies that incorporate behavioural change readiness can exert favourable influence on patient's interest, knowledge, and perceived compliance to the suggested lifestyle modifications.

Keywords

cardiovascular disease, information personalization, patient education, SCORE, Stages of Change

1. Introduction

Cardiovascular disease (CVD) is a major disease burden in terms of both mortality and health-related quality of life. Canadians run a high risk of developing CVD: 8 out of 10 individuals have at least one modifiable risk factor [1]. The literature is quite clear with regards to the prevention of heart disease through the role of educational interventions that target risk factor modification and healthy lifestyle changes [2].

Patient-directed intervention is well-evidenced and has been shown to empower patients to self-manage disease risk and improve their quality of life [3]. Despite demonstrated benefits,

too few patients have disease risk reduction program opportunities or take advantage of those that are available [4]. One reason for the limited uptake of risk reduction programs is that conventional health education is generally designed to include as much information as possible either for the general public or a specific patient population. This often results in lengthy, complex and irrelevant materials for the recipient. Patients prefer to receive information that is custom-tailored to their individual needs and circumstances [3] and evidence shows that personalized information is more likely to be read, remembered, experienced as personally relevant, and in turn has a greater impact in motivating patients to make the desired change in behaviour [5].

Human behaviour is a key determinant of health improvement. Behavioural scientists assert that although one can organize information to make it more understandable, usable, and appealing, it cannot be guaranteed that the pertinent healthcare information will bring about behaviour change in all people. However, healthcare education, when embedded in a well-designed, behaviour theory-based intervention can make a difference and is consistent with the current emphasis on using evidence-based interventions in public health [6]. A behaviour change model that has been very successful in guiding interventions to increase adoption and compliance with healthy lifestyle changes is Prochaska's Transtheoretical Model (TTM), commonly known as Stages of Change [7].

In this paper we present a personalized patient education program for the management of cardiovascular disease risk. The PULSE project—Personalization Using Linkages of SCORE and behaviour change readiness to web-based Education—provides patient education that is personalized based on the patient's CVD risk assessment and readiness to change their behaviour(s). The PULSE educational process is initiated by a healthcare professional in a primary care setting. The program is based on a patient profile generated by combining: (a) an electronic patient data capture template (DCT) that contains a set of evidence-based parameters for patient description and disease evaluation; (b) the Systematic COronary Risk Evaluation (SCORE) algorithm [8] to estimate a ten-year risk for fatal CVD; and (c) a Stage of Change determination model that determines messages consistent with the patient's behaviour change processes, decisional balance, and self-efficacy. The personalization decision logic, based on Canadian clinical guidelines and validated behaviour change research, is represented in terms of Medical Logic Modules (MLM). The educational interventions are designed to address both medical and psychosocial aspects of risk management and, as such, we combine staged lifestyle modification materials and non-staged messages based on Canadian clinical guidelines to motivate personal risk management. Finally, a web-based delivery mechanism is proposed to present the personalized education material to the patient.

2. Background

2.1 CVD Risk Assessment

The concept of risk assessment and reduction, introduced by the Framingham Heart Study (FHS) forms the cornerstone of preventive cardiology. The risk status of persons without manifest CVD varies greatly, and this variability mandates a range in the intensity of interventions. As such, effective primary prevention requires an assessment of risk to categorize patients for selection of appropriate interventions [9]. The FHS risk score, using a point system model, predicts the 10-yr risk of coronary heart disease (CHD) events.

A more recent predictive model of cardiovascular disease events with increasing desirability in Canada is SCORE. Initiated in Europe, this predictive equation estimates an individual's 10-yr risk of cardiovascular death. The SCORE equation estimate has been developed from pooled datasets of 12 European cohort studies involving more than 200,000 persons with

more than 2.7 million person years of follow-up [8]. This predictive model features a number of advantages over FHS. These include its: (i) restriction to only fatal CVD events; (ii) applicability to both CHD and stroke; (iii) ability to show changes in outcomes based on changes in risk factor values, and (iv) potential for calibration to specific populations if outcomes and epidemiological risk factor data are available for the population of interest [7]. The SCORE model is seemingly disadvantaged by its unfamiliarity to North American health care professionals; however, this is changing. The Canadian Cardiovascular Society has proposed Canadian health professionals use HeartSCORE to help manage CVD risk [10].

2.2. Behaviour Change

Research and experience led to the observation that initiating and maintaining positive behaviour changes are challenging for most people. The Transtheoretical Model of intentional behaviour change is a stage-based model founded on 25 years of research. As part of their "Transtheoretical" strategy, model originators consciously incorporated and built upon the strengths of their predecessors (the Health Belief Model, the Theory of Reasoned Action and of Planned Behaviour and the Social Cognitive Theory), encompassing many concepts from these previously developed models [11]. The TTM matches the change principles and processes to each individual's current stage of change, in order to guide them through the process of modifying problem behaviour(s) and acquiring positive behaviour(s) [12]. The model consists of three key constructs. The first construct is the temporal dimension or Stage of Change - a characterization of a person's readiness to take and sustain action. The five Stages of Change are: precontemplation, contemplation, preparation, action, and maintenance. The second construct includes the fundamental experiential and behavioural processes of change. This dimension represents how change occurs from one stage to another. The five experiential processes include consciousness raising, dramatic relief, self-re-evaluation, environmental re-evaluation, and self-liberation. The five behavioural processes include helping relationships, counter-conditioning, stimulus control, social liberation, and contingency management. Each of these processes has been identified as facilitating change to the next stage when employed in messages at a stage appropriate to that process [12]. The third construct includes measures that are sensitive to progress through the stages, such as decisional balance and self-efficacy/temptation measures. The latter measure examines the patient's confidence to cope with a high-risk situation without relapsing to their unhealthy behaviour. The decisional balance refers to why change occurs; an individual's weighing of the pros and cons of changing behaviour. The pros represent the facilitators of change, while the cons represent the barriers to change. In general, a predictable pattern is observed between the stages of change and decisional balance suggestive of the need of placing emphasis on increasing consciousness of those factors supportive of a given behaviour change. The use of a fully integrated TTM to inform the design of personalized messages has been effective for intervening across a broad range of health-related behaviours [13, 14]. Figure 1 displays the abstraction from the literature of the integrated TTM variables for use in personalizing educational messages.

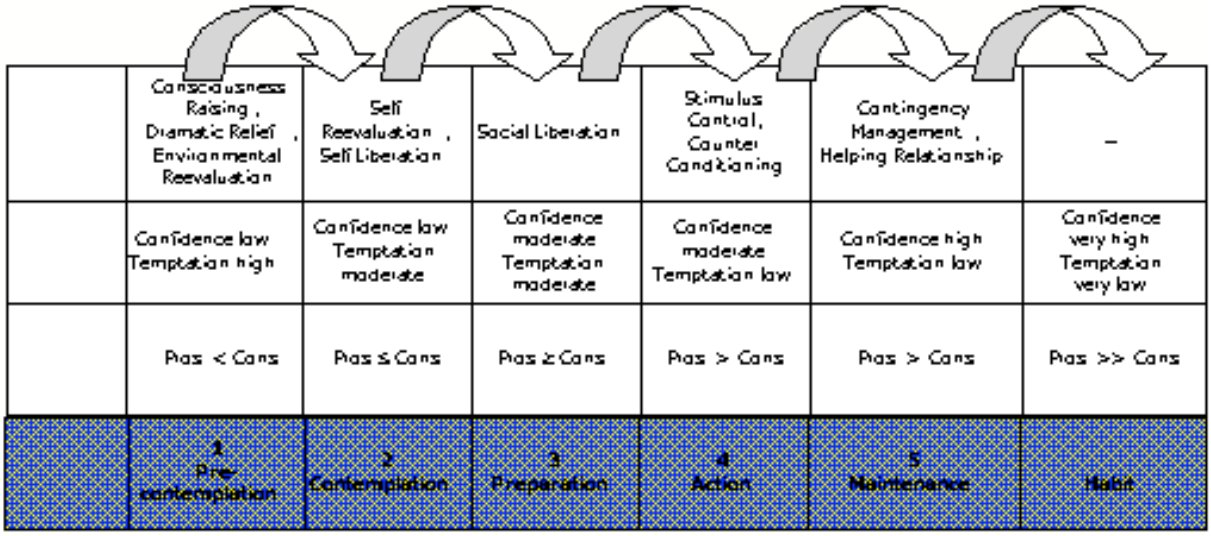

Figure 1: Integrated TTM constructs for use in personalizing educational messages.

2.3. Information Personalization for Healthcare

Personalized educational interventions have been found to be more effective than non-individualized ones in changing important health behaviours [15, 16]. The use of intelligent interactive technology to generate information that is specifically adapted to one patient is broadly referred to as computer tailoring in healthcare. According to Jones et al., [17] the use of computer technology to personalize information requires at least five components. These include: 1) a profile of the patient, 2) a digital library containing all the health education messages, 3) a mapping schema that generates the appropriate messages, 4) a document template for appropriate allocation and display of educational messages, and 5) a medium to deliver the message to the intended user.

Personalizing information at the individual level can occur in numerous ways including the *adaptation* of the original message or source of information, altering the change strategy, and/or adjusting the method of delivery or display. The process of 'how' the information is personalized, as per a patient's profile, is based on the information personalization approach suitable for the task at hand—i.e. taking into account the salient patient parameters that can form the basis for selecting/adapting relevant information content, the mapping of the patient parameters to specific educational content in order to establish a decision logic that guides the information personalization process to yield a personalized information content, and the delivery medium through which information is to be provided to the patient. The above elements of an information personalization approach are implemented as an intelligent computer application, such as a recommender system, that incorporates computing methods to achieve the various information personalization tasks. For example, behavioural and clinical data specific to relevant risk factors can be compared with clinical guidelines and recommendations or with the patterns of peers. This component of the 'how' guides the requirements of input data collection. In terms of the fundamental computer mechanics, the tailoring expert system analyses input data and links them with a feedback and information source. This information source is a message library that contains appropriate feedback and materials for each input datum. It is the algorithms ('if-then' statements) in the expert system that link individual results to a message library and form the personally relevant information. A tailoring matrix is often used in this regard to summarize the characteristics that have to be assessed and describe specific combinations of characteristics that lead to a certain message. The algorithms in the expert system have an additional role; they also assemble the personally relevant information into a predetermined format, which can be delivered and

displayed in various ways. In doing so, general principles of attractiveness and readability are applied, as well as methods to ensure coherence of the integrated messages in the intervention. Thus, content and framing of all possible message combinations must be taken into account. The accessibility and capability of the Web to rapidly present interactive, customizable and multi-media information, offers many advantages for tailoring over interventions that deliver messages via paper, laptop computer or kiosk [18]. Web dissemination of tailored health interventions has shown promise and demonstrated positive impact on determinants of behaviour change [16].

3. Material and Methods

The following components relate to the development and implementation of the PULSE program. The development follows the framework laid out by Jones et al. [17], with an additional component added – an evidence-based data capture template.

3.1. Data Capture Template

We use the validated, commercially available Wellsource Coronary Risk Profile as the basis for our data capture model for collecting patients' demographic, behavioural, and clinical risk factor characteristics. Cross-referencing collection parameters with the global INTERHEART Study [19] indicates that the nine risk factors accountable for over 90% of the risk of acute myocardial infarction were captured in our DCT. Our data capture template inherently comprises 28 evidence-based parameters for patient description and disease evaluation and clinically significant relationships between the parameters. These parameters are used to design our objective patient profile to support the personalization of educational material, such as age, gender, personal and family health history, smoking status, amount of regular exercise, eating practices, alcohol consumption, stress, depression, lipid and blood pressure (BP) values, and weight and glycemic control values. Additionally, a patient's readiness to make lifestyle changes is obtained for each risk factor.

3.2. Patient Profile

The patient profile comprises three components, where each component collects patient parameters for specific personalization purposes. The three components are:

(1) *CVD Risk Profile*: This component directs the selection of clinical guidelines for all risk factors based on the patient's risk. Risk is determined by the SCORE algorithm that estimates the 10-yr cardiovascular risk of death. Patient data on age, gender, smoking, systolic blood pressure (SBP), and total cholesterol to HDL (High-Density Lipoprotein) cholesterol ratio (TC:HDL) are used to calculate the patient's risk category as percentages that are translated as follows into tertiles of risk: ≤1% (low risk), 1 - 5% (moderate risk), and >5% (high risk). If diabetes is indicated as a patient's personal health problem, the SCORE is adjusted as indicated by Conroy et al. [12]. Additionally, the CVD risk profile is graphically displayed in a separate section of the final document.

(2) *Staged Risk Factor Profile:* This component directs selection of fully integrated TTM messages consistent with the patient's stage of change for specific modifiable risk factor behaviours - smoking, being overweight, stress, depression, and physical inactivity. The stage of change is determined by a patient's response to questions relating to her/his readiness to modify risk factor behaviours. The patient's responses infer the Stage of Change using a simple Stage Determination Model. A patient's readiness to change is placed into one of the five Stage categories. For example: Are you ready to make lifestyle changes to improve your health? a) No present interest in making any lifestyle change infers

Stage1; b) Thinking about making a lifestyle change infers Stage 2; c) Making plans to achieve this change infers Stage 3; d) Recently started implementing this change infers Stage 4; and e) Have been doing this for six months or more infers Stage 5.

(3) *Non-staged Risk Factor Profile:* This component directs selection of messages for all non-staged risk factors, such as eating practices, alcohol intake, Lipids, BP, glycemic control (Fasting Plasma Glucose (FPG)), and personal and family history. Figure 2 illustrates the generation of the patient profile which directs the personalized patient education.

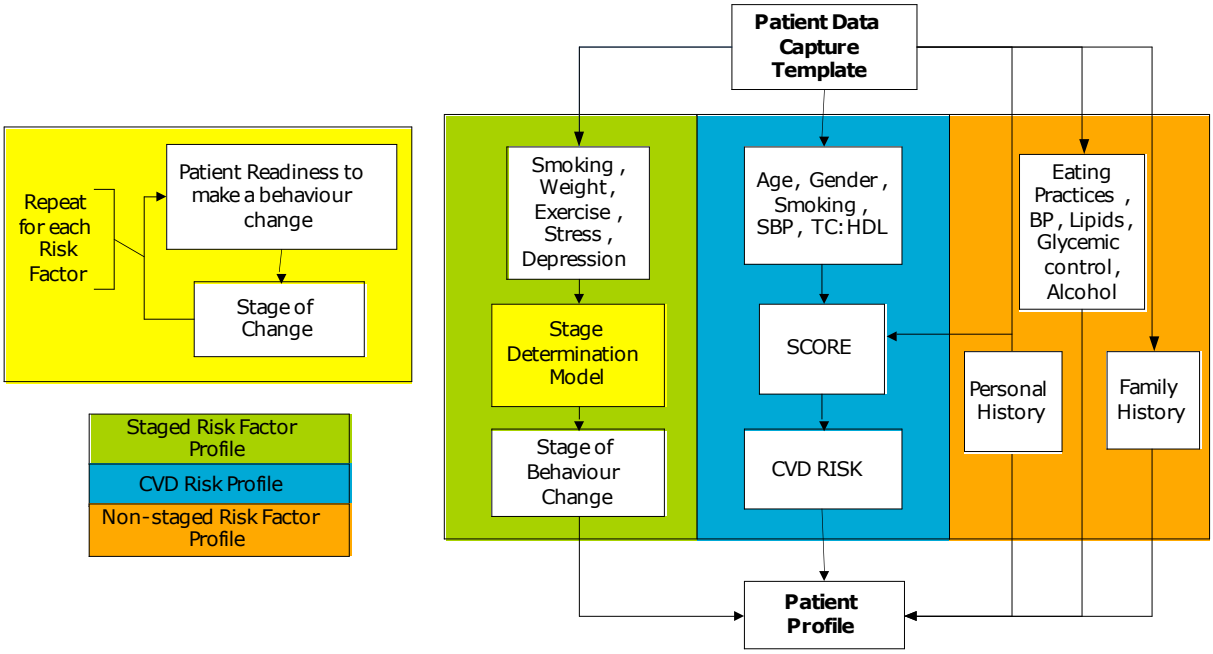

Figure 2: Generation of the Patient Profile

3.3. Message Library

In the PULSE program, the educational interventions are based on a combination of staged lifestyle modification materials and risk-specific messages derived from clinical guidelines. The messages library composes three sections: (1) *CVD Risk-matched Guidelines*; (2) *Staged Risk Factors*; and (3) *Non-staged Risk Factors*.

The various education materials are converted from print to electronic format and broken down into small "snippets of information" in order that numerous combinations of educational information may be used in the personalization process. For example, educational material on weight control was decomposed into a variety of general, gender-specific, and Stage of Change messages (see Figure 3 below). Accordingly, an overweight female with a behaviour change readiness of 'No present interest in making any lifestyle change' would receive general introductory, gender-specific, and motivational messages and Stage 1 weight control education, whereby a male with a healthy weight but with obesity in his family would receive a family health history message only. Each snippet is <tagged> and stored in an SQL (Standard Query Language) database. The <tag> for each snippet follows an indexing schematic which provides mapping ease to the patient profile for personalization purposes (e.g. <smoking>).

The *CVD Risk-matched Guidelines* section contains risk-matched target values and textual recommendations for the following risk factors – smoking, blood pressure, exercise, stress, depression, eating practices (as dietary recommendations), lipids (TC:HDL cholesterol, LDL cholesterol, and triglycerides), glycemic control (FPG, Glycohemoglobin), alcohol, and weight

management (Body Mass Index and waist circumference). The target values and textual recommendations for all risk factors are based on the Canadian guidelines for cardiovascular rehabilitation and CVD prevention, diabetes, dyslipidemia, and hypertension.

The *Staged Risk Factors* section contains fully integrated TTM (staged) educational documents addressing five risk factors – smoking, obesity, stress, depression, and physical inactivity. These staged risk management materials are commercially produced by Pro-Change Behavior Systems, Inc. and have been validated in clinical trials for smoking cessation, stress management and weight management. The *Staged Risk Factors* section of the message library follows a decision tree indexing schematic based on the needs of the patient and as outlined in Figure 3 below. This indexing format is used for all three sections of the message library.

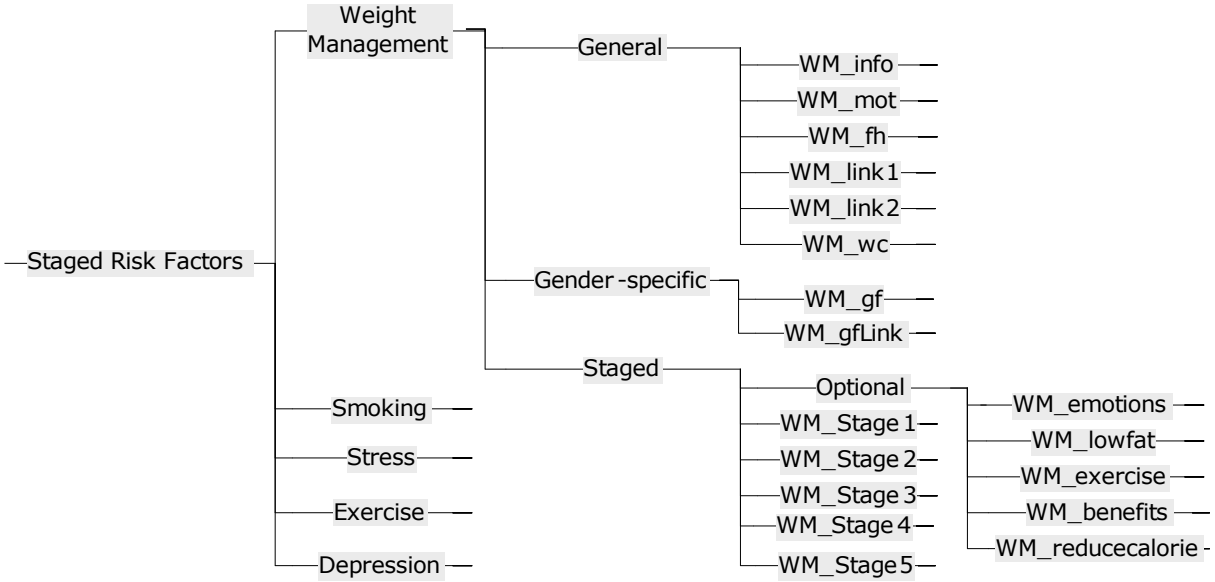

Figure 3: Staged Risk Factors Indexing Schematic

The final section, the *Non-staged Risk Factors* section contains non-staged risk management materials addressing two CVD risk conditions – age and gender – and five CVD risk factors – blood pressure, eating practices, lipid profile, glycemic control, and alcohol. Messages in this section were abstracted from three valued sources: (1) the Heart & Stroke Foundation; (2) the Nova Scotia Cardiac Rehabilitation Centre; and (3) the Public Health Agency of Canada.

3.4 Decision Logic

Given a patient profile and a message library containing an assortment of education interventions, the personalization algorithm involves the selection of the most relevant set of messages based on the patient's individual profile. As per our personalization approach, we designed a tailoring matrix to summarize the specific combinations of characteristics from the patient parameters assessed that lead to a certain message.

Personalization is achieved through the processing of a set of symbolic rules that model the decision logic for information personalization—the decision logic maps the profile elements to specific messages. The decision logic, which controls the personalization outcome, is represented as MLM (Medical Logic Modules)—MLM is a standard for independent units composing a series of rules in health knowledge bases.

We develop a rule-based inferencing engine that incorporates the MLM-based decision logic. The entire decision logic, sets of MLMs, is implemented in Java and represented as a comprehensive decision tree describing each of the risk factors and risk conditions contained

in the patient profile. Each MLM consists of four parts: an evoking event, logic, action, and data mapping. The logic contains "if-then" rules, where the IF part of the rules contains variables for one or more patient profile elements. Using case statements, if the IF part of the rule *is not* satisfied then engine directs the execution of the next case statement. If the IF part of the rule *is* satisfied—i.e. the patient's profile matches the rule constraints then the rule fires and the THEN part of the rule becomes available for execution. Typically, the THEN part contains a list of messages that are selected as part of the patient's personalized educational material. The sample code below illustrates a simplified MLM for the Exercise case. In the example, the rule constraints of three patient profile elements (exercise, gender, readiness) were satisfied firing the action of the rule; the writing of relevant exercise messages for that patient.

```
//maintenance:
      //title: Messages based on Physical Activity Level of Patient;;
      //filename: Exercise;;
      //version: 1.00;;
      //institution: Dalhousie University;;
      //author: Name1;;
      //specialist:Name2;;
      //date: 2006-2-14;;
      //validation: testing;;
// library:
      //purpose: Get message tags for patients about their level of
            //physical activity;;
      //explanation: When a patient indicates her/his level of physical
            //activity in one week, it affects the personalised messages;;
      //Keywords: Regular Exercise, Physical Inactivity, CVD;;
// knowledge:
      //type: data-driven;;
      //data:;;
      //evoke: data entered from the DCT;;
      logic:      if Exercise=five or more times per week then conclude
                  false:
                  elseif Exercise=no regular exercise and Gender=Female and
                  Readiness to change=no present interest in making any
                  lifestyle change then conclude true:
                  endif;;
      action:     write "<Exercise motivation> and <Exercise Female> and
                  <Exercise Stage1> and <Exercise Link2>";;
//end:
```

3.5 Display Template

We created a document structure, comprising four parts, to organize and present the chosen messages for each patient in a coherent and consistent manner (Figure 4). The four parts are as follows: (1) The *Introductory Page* provides a brief description about the personalized education document; (2) The *CVD Risk Profile* offers a graphical display of this patient's risk, including a relative risk chart which displays the contribution of risk factors to total risk; (3) The *Progress Page* provides a graphical display of changes in a patient's risk over time; (4) The *Risk Factor Management* section provides personalized information on each risk factor relevant to the patient. Each risk factor has its own section complete with an introductory

brief, patient's current results, evidence-based target values, and lifestyle modification and risk management education.

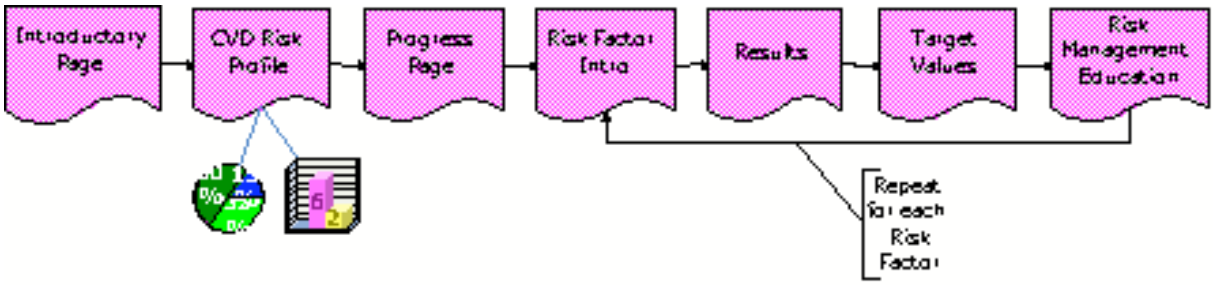

Figure 4: Document Structure

3.6 Delivery Method

The PULSE educational process is initiated by a healthcare professional in a primary care setting. The practitioner enters the web-based system with a username and password and begins entering data into the DCT in consultation with the patient. Once all data is submitted, our expert system generates the personalized document. The document is rendered in HTML (Hypertext Markup Language) on the computer screen in a web browser for view by the patient and her/his allied health professional. A printable version is available for patients who do not have access to a computer. Patients have view and print access to their educational document at any time by logging onto the website.

3.7. Implementation System

The web-based implementation system (Figure 5) is used to personalize the education by allowing the patient's data to be entered, displaying the individualized results. The popular open-source programming language used for developing dynamic web content, PHP (Hypertext Preprocessor), is employed to implement data capture. Depending on the data type for the decision variable, the input data is captured using radio button, check-box, text-box, or drop-down menu format. The submitted stylesheet evokes storage of the patient data in an SQL database. The rules engine is fired by the passage of the patient data to it. The decision logic in terms of MLM is implemented using the Java programming language as it facilitates the subsequent rule-based inferencing. The MLM processes the data on logic statements to determine the patient profile. Once all data is processed, the rules engine uses this information to select appropriate messages from the message library. PHP is once again employed to insert the information into the display template producing and delivering a final education document that is personalized to each patient based on her/his data via a web browser. All information is securely stored on a central server.

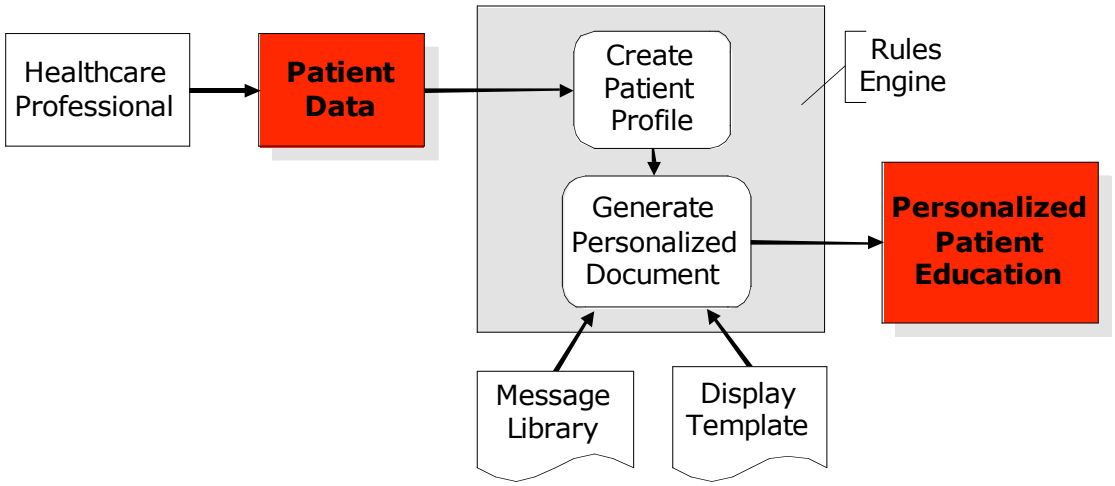

Figure 5: Implementation System

4. Working Example

Two hypothetical patients illustrate the personalization of education from the PULSE system. In this example only 12 of the 28 patient parameters are used.

Ms. Adams is a 48 year old diabetic woman with TC:HDL cholesterol of 6.2 mmol/L, FPG of 6.3 mmol/L, and BP of 135/88 mmHg. She is a non-smoker and indicates no depression. She exercises twice per week and reveals her readiness to change as making plans to achieve this change. In this example, Ms. Adams' SCORE is 2% (Moderate). She receives 14 messages containing information relevant to her including: gender-specific information and exercise stage 3.

Mr. Brown is a 60 year old hypertensive man with TC:HDL cholesterol of 4.3 mmol/L, FPG of 5.8 mmol/L, and BP of 145/98. He is a smoker and is depressed. For both these risk factors he indicates a readiness to change as thinking about making a lifestyle change. He specifies heart disease and hypertension in his family health history. He reveals no regular exercise and a readiness to change this behaviour as no present interest in making any lifestyle change. In this example, Mr. Brown's SCORE is 10% (High). He receives 21 messages containing information relevant to him including: smoking stage 2, exercise stage 1, and depression stage 2.

5. Evaluation Strategy

An evaluation study will be conducted to determine whether web-based personalized educational strategies that incorporate behavioural change readiness will exert favourable influence on patient's interest, knowledge, and perceived compliance to the suggested lifestyle modifications. The subjects will include approximate forty patients aged 40-65, without manifest disease, recruited from a single family practice in Halifax, Nova Scotia. Physicians will be asked to confirm eligibility. Potential participants will be provided an information sheet with study coordinator contact information. Upon contact from a potential participant, consent to participate in the study and a scheduled 1-hour 'intervention' date will be ascertained. Eligible participants will be randomized into one of three intervention groups: (1) web-based personalized; (2) web-based non-personalized; and (3) paper-based non-personalized. The study design comprises a patient survey using a three-group randomized between-subjects arrangement with post intervention measures. Intervention groups 1 and 2 will be given access to the educational materials online, while intervention group 3 will

receive paper-based materials. The patient survey contains 23 close-ended questions (using a 5-point Likert scale). Time taken by the patient to read and stay engaged in the intervention will also be recoded. Quantitative data will be analyzed using descriptive statistics, as well as inferential statistics for between group analyses. Ethics approval for this study has been received.

6. Concluding Remarks

In Canada, there is a realization that "Cardiovascular diseases place a significant burden on Canadians and our health care system more than any other illness" and that "We need to help Canadians reduce their risk;" this according to the Honourable Anne McLellan, the previous Minister of Health [20]." In the PULSE project we have proposed a novel computer-tailored patient education strategy that features: (a) use of SCORE for CVD risk assessment; (b) use of behaviour change inputs to personalize the educational content; (c) use of an objective patient DCT currently in operation; (d) leveraging Canadian clinical guidelines for deriving the decision logic and the corresponding educational intervention; and (e) personalization of educational material. The realization for personalized education information compared to generic information has led to various computer-tailored programs. We believe that quality and timely patient-directed interventions are a healthcare service that can help reduce disease risks and deal with risk management by influencing changes in patients' behaviours through the provision of up-to-date and relevant lifestyle modifications and change strategies.

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List of Abbreviations

The following is a list of abbreviations for terms in common use throughout this paper.

Table 1: An alphabetical list of initials used

Abbreviation	Complete Word
BP	Blood Pressure
CHD	Coronary Heart Disease
CVD	Cardiovascular disease(s)
DCT	Data Capture Template
FHS	Framingham Heart Study
FPG	Fasting Plasma Glucose
HTML	Hypertext Markup Language
LDL	Low-Density Lipoprotein
MLM	Medical Logic Modules
PHP	Hypertext Preprocessor programming language

Abbreviation	Complete Word
PULSE	Personalization Using Linkages of SCORE and behaviour change readiness to web-based Education
SBP	Systolic Blood Pressure
SCORE	Systematic COronary Risk Evaluation
SQL	Standard Query Language
TC:HDL	Total Blood Cholesterol to High-Density Lipoprotein Cholesterol ratio
TTM	Transtheoretical Model