© *The Journal on Information Technology in Healthcare* 2008; **6**(1): 73–82

Generating Personalised Cardiovascular Risk Management Educational Interventions Linking SCORE and Behaviour Change

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ABSTRACT

Quality and timely patient education can reduce cardiovascular disease risk. The PULSE (Personalisation Using Linkages of SCORE and behaviour change readiness to Web-based Education) project objective is to design a Web-based personalised educational intervention for the management of cardiovascular risk. The intervention is based on a patient profile generated by combining: (i) an electronic data capture template (DCT); (ii) the Systematic COronary Risk Evaluation (SCORE) algorithm for ten-year risk assessment for fatal cardiovascular disease; and (iii) a Stage determination model for behavioural change readiness. The DCT inherently contains a set of evidence-based parameters for disease evaluation and management.

The SCORE estimation directs the selection of clinical guideline target values for risk factors. The patient's Stage of Change determines messages consistent with the individual's behaviour change processes, decisional balance, and self-efficacy. The interventions are designed to address both medical and psychosocial aspects of risk management and, as such, staged lifestyle modification materials and non-staged messages based on Canadian clinical guidelines are combined to motivate personal risk management. The personalisation decision logic is represented in Medical Logic Modules and implemented in Java. The system design is a Web-based system so that it can generate and deliver personally relevant educational materials to the patient. The PULSE educational process is initiated by a healthcare professional in a primary care setting. A system prototype has been developed and evaluated including system testing specific to the accurate functioning of the personalisation decision logic – i.e. accurate selection of personalised messages for a given patient profile.

INTRODUCTION

Cardiovascular diseases (CVD) place a significant burden on health professionals, patients and their care-givers, and result in significant healthcare costs[1]. It is well-recognised that CVD morbidity and mortality are greatly affected by unhealthy

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lifestyle choices. This aspect can potentially be addressed through risk factor modification and healthy lifestyle changes[2].

Risk factor modification is commonly addressed through patient education. This 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, many patients do not have disease risk reduction program opportunities or take advantage of those that are available[4]. One reason for this is that conventional health education is generally designed to include as much information as possible, often resulting in lengthy, complex and irrelevant materials for the recipient. Patients prefer to receive information that is personalised to their individual needs and situation and evidence shows that personalised information is more likely to be read, remembered, appreciated as being personally relevant, and ultimately have an impact in motivating patients to change their desired behaviour[3,5].

Human behaviour is a key determinant of health improvement. Education, when embedded in a well-designed, evidence-based intervention, can make a difference and is consistent with the emphasis on using evidence-based interventions in public Health[6]. One model that has been successful in guiding interventions to comply with healthy behaviour changes is the Transtheoretical Model (TTM), or Stages of Change[7].

Personalisation is an important factor in the success of patient educational programs[8]. Personalised educational interventions have been shown to be more effective than their non-tailored counterparts in changing important health behaviours[9]. Web-based patient education programs offer a viable and alternate medium for disseminating personalised education and monitoring services to patients[10].

In this paper, we present our approach and prototype system for generating personalised educational material for patients. Our approach is based on the fundamental observation that the efficacy of any patient educational intervention is dependent on the patient's readiness to change their behaviour. To enhance the success of our system we use both CVD risk assessment and behavioural change readiness tools to determine the patient's profile. Based on the profile, our personalisation algorithm selects relevant messages to compose the educational material for an individual patient. We use SCORE (Systematic COronary Risk Evaluation) for risk assessment and Stages of Change for behaviour change readiness assessment. The educational material is derived from Pro-Change Behaviour Systems Inc. and Canadian clinical guidelines. The personalisation decision logic is represented in terms of Medical Logic Modules (MLM), implemented in Java. Finally, a Web-based delivery mechanism is proposed to deliver the personalised education material to the patient.

RISK ASSESSMENT

The concept of risk assessment and reduction, introduced by the Framingham Heart Study (FHS), forms the cornerstone of preventive cardiology. A more recent

predictive model of CVD events that is receiving increasing attention in Canada is SCORE[11]. This predictive equation estimates an individual's absolute 10-yr cardiovascular risk of death, and has a number of advantages over FHS including its:

- Restriction to only fatal CVD events
- Applicability to both coronary artery disease and stroke
- Ability to show changes in outcomes based on changes in risk factor values
- Potential for calibration to specific populations if outcomes and epidemiological risk factor data are available for the population of interest.[7]

BEHAVIOUR CHANGE

Research and experience indicate that initiating and maintaining positive behaviour changes is challenging for most people. Prochaska's Transtheoretical Model (TTM) of intentional behaviour change is a stage-based model founded on 25 years of research. The model 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 behaviours and acquiring positive behaviours[12]. The model consists of three key constructs. The first construct is the temporal dimension or Stage of Change – a characterisation 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-reevaluation, environmental reevaluation, 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 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 an individual's weighing of the pros and cons of changing behaviour. In general, a predictable pattern is observed between the stages of change and decisional balance suggestive of the need to place emphasis on increasing consciousness of those factors supportive of a given behaviour change.

Figure 1 displays the abstraction from the literature of integrated TTM variables for use in personalising educational messages. The use of fully integrated TTM constructs to inform the design of personalised messages has been shown to be effective for intervening across a broad range of health-related behaviours[13]. For example, studies on stopping cigarette smoking have shown that interventions tailored to a smoker's stage were more often successful than non-tailored interventions in promoting forward stage movement[14].

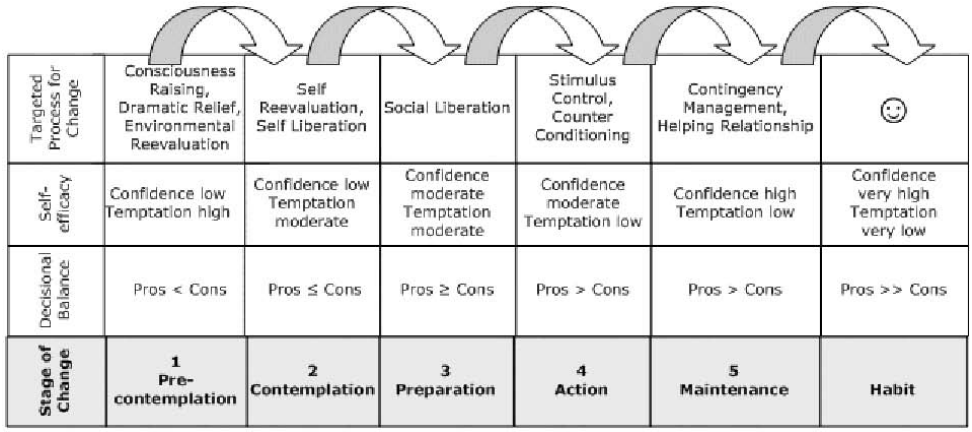

Figure 1. *Integrated Transtheoretical Model (TTM) constructs*

INFORMATION PERSONALISATION FOR HEALTHCARE

Computer-tailored education systems can conduct comprehensive assessments of health-related behaviours at an individual level[15]. Personalising information at this level can occur in numerous ways including adapting the message or source of information, and/or the method of delivery. The process of how the information is personalised is based on which variables are of relevance and interest to both the provider and the consumer. For example, behavioural and clinical risk factor-specific data can be compared with clinical guidelines or with the patterns of peers. The use of computer technology to personalise information has been suggested to require at least:

- A user profile
- A digital library containing all messages
- A mapping schema that generates the appropriate messages
- A document template for appropriate allocation and display of messages
- A medium to deliver the message to the intended user

MATERIAL AND METHODS

The following elements relate to the development and evaluation of the PULSE program. The development follows the framework laid out by Jones *et al.*[16], with an additional component added – an evidence-based data capture template.

Patient Data Collection (DCT) and Profile Generation

We used 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[17] indicates that the nine risk factors accountable for over 90% of the risk of acute myocardial infarction (MI) were captured in our DCT. In our opinion the DCT inherently comprises a set of evidence-based parameters for patient description and disease evaluation and management. The parameters include the following risk conditions and risk factors: age, gender, personal and family health history related to CVD, smoking status, amount of regular exercise, eating habits, alcohol consumption, weight control values, stress, depression, lipid values, blood pressure (BP) values, glycaemic control values, and behaviour change readiness. As these parameters provide the core data with which experts in the field make decisions for patients with respect to CVD prevention, they were used to create our objective patient profile.

The complete patient profile is designed in three parts for ease of mapping (by way of the personalisation decision logic) to the message library. Each component of the profile collects patient parameters from the DCT for specific personalisation purposes.

The three components are:

1. CVD Risk Profile – This is determined through the SCORE algorithm that estimates the 10-year total cardiovascular risk of death. Patient data on age, gender, smoking, systolic blood pressure, total cholesterol and HDL cholesterol ratio is used to calculate the patient's risk category as a percentage. This is translated as follows: ≤1% (low), 1-5% (moderate), >5% (high). If the patient is diabetic the SCORE is

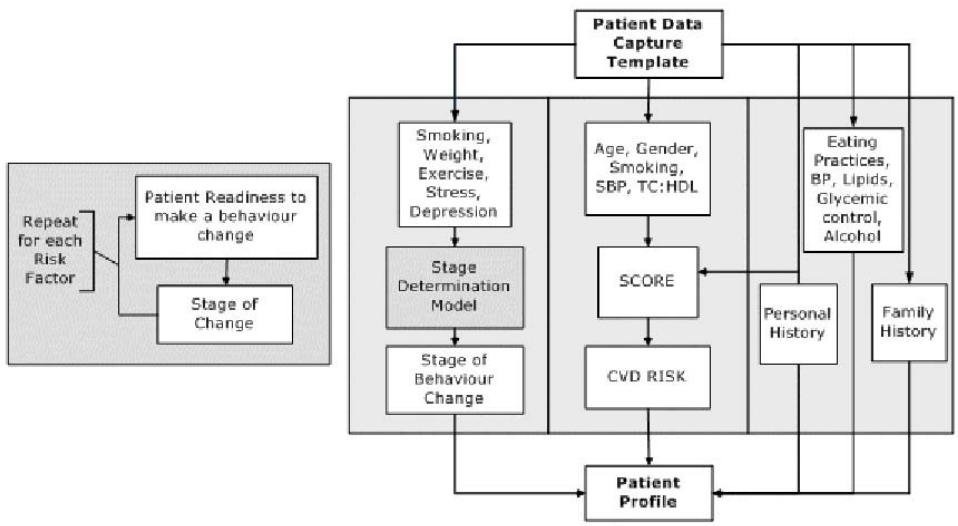

Figure 2. *Patient profile model*

BP = Blood Pressure, CVD = Cardiovascular Disease, HDL = High Density Lipoprotein, SCORE = Systematic Coronary Risk Evaluation, SPB = Systolic Blood Pressure, TC = Total Cholesterol.

adjusted as indicated by Conroy *et al*[11]. The patient's risk category (e.g. high) directs the selection of risk-matched target values for all relevant risk factors.

2. Staged Risk Factor Profile – This depicts the patient's Stage of Change for specific modifiable risk factor behaviours. The Staged Risk Factor Profile is determined by a patient's response to questions relating to her/his readiness to change modifiable risk factor behaviours – smoking, being overweight, stress, depression, and exercise. 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.

3. Non-staged Risk Factor Profile. This is determined by additional risk factor values – eating habits, alcohol consumption, serum Low Density Lipoprotein (LDL) and Triglyceride values, diastolic blood pressure, fasting blood glucose, and personal and family health history. Figure 2 illustrates the components of the patient profile.

Message Library

In the PULSE program, we use a combination of staged lifestyle modification materials and risk-specific messages based on clinical guidelines to provide a valid use of behaviour change theory and Canadian sources of clinical and lifestyle modification education. The Staged risk management materials are commercially produced by Pro-Change Behavior Systems, Inc. The risk-matched target values for all risk factors are based on the following Canadian guidelines:

- Cardiovascular rehabilitation and CVD prevention
- Diabetes
- Dyslipidemia
- Hypertension

In addition pre-written, non-staged risk management materials were included from three trusted and valued sources: Heart & Stroke Foundation, Nova Scotia Cardiovascular and Pulmonary Health in Motion Cardiac Rehabilitation Program, and Public Health Agency of Canada.

The various sourced materials of the message library were converted from print to electronic format and broken down into "snippets" of information (independent body of information pertaining to a single risk factor topic) that could be variously combined in order to produce individualised educational messages. Each snippet was tagged and stored in a MySQL database. The <tag> for each snippet follows an indexing schematic which provides mapping ease to the patient profile for personalisation purposes (e.g. <smoking>).

Decision Logic

Given a patient profile and a message library containing an assortment of education interventions, the personalisation mechanism involves the selection of the most

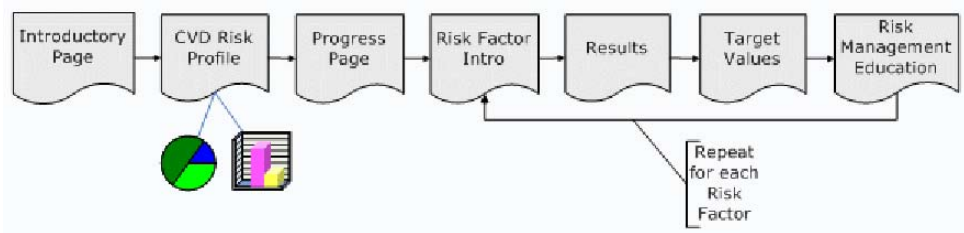

Figure 3. *PULSE Personalised Document Structure*
CVD=Cardiovascular Disease

relevant set of messages based on the patient's profile. Personalisation is achieved through the processing of a set of symbolic rules based on decision logic—the decision logic maps the profile elements to specific messages. We developed a rule-based inferencing engine that incorporates the decision logic. To represent our medical knowledge we use MLMs, a standard for independent units composing a series of rules in health knowledge bases. The entire decision logic set 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. The logic contains "if-then" rules, where the IF part of the rules contains variables for one or more patient profile elements. 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 personalised educational material.

Display Template

An overall document structure was created to organise and present the chosen messages for each patient in a coherent manner (Figure 3).

The *Introductory Section* provides a brief description about the personalised intervention.

The *CVD Risk Profile* offers a graphical display of the patient's risk.

The *Progress Page* provides a graphical display of changes in a patient's risk over time.

The *Risk Factor Management* section provides 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, lifestyle modifications and risk management education.

Implementation and Delivery

The healthcare practitioner enters the Web-based system using a username and password, and begins entering data into the DCT in consultation with the patient.

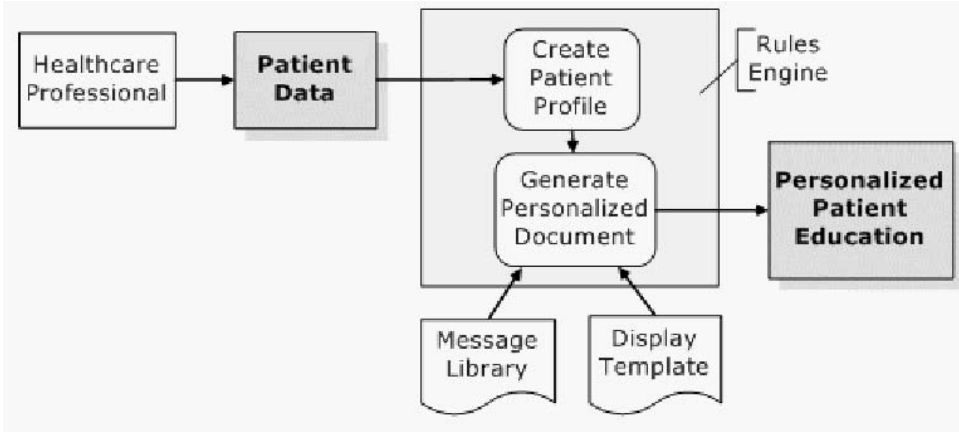

Figure 4. *PULSE System Model*

Once all data are submitted and passed to the rules engine, the system begins generating the personalised document. 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. The information is inserted into a display template and rendered in HTML (Hypertext Markup Language) on the computer screen in a web browser for viewing by the patient and her/his allied health professional. A printable version is available for patients who may not have access to a computer. Patients can access, view and print their educational document at any time by logging onto the website. Figure 4 illustrates the PULSE system model.

Evaluation

In order to test the functionality of the system, a system prototype was developed. To evaluate whether the PULSE system is functioning accurately (in terms of personalisation decision logic) a test regime was created whereby various hypothetical user profiles were input and the output compared to the expected results. Test profiles were chosen which varied in age, gender, and clinical and behavioural characteristics of patients. The determination of all expected messages for each test case was made by way of manual examination of the entire personalisation decision logic – i.e. matching the patient profile to the message tags. PULSE was executed based on the test suite and a pass/ fail conclusion was made. The determination of a pass/fail conclusion was made by examining the resulting document for inclusion of all, and only, the expected messages.

RESULTS

Personalisation of education from the PULSE system can be illustrated using 2 hypothetical patients. In this example only 12 of the 28 patient parameters are used.

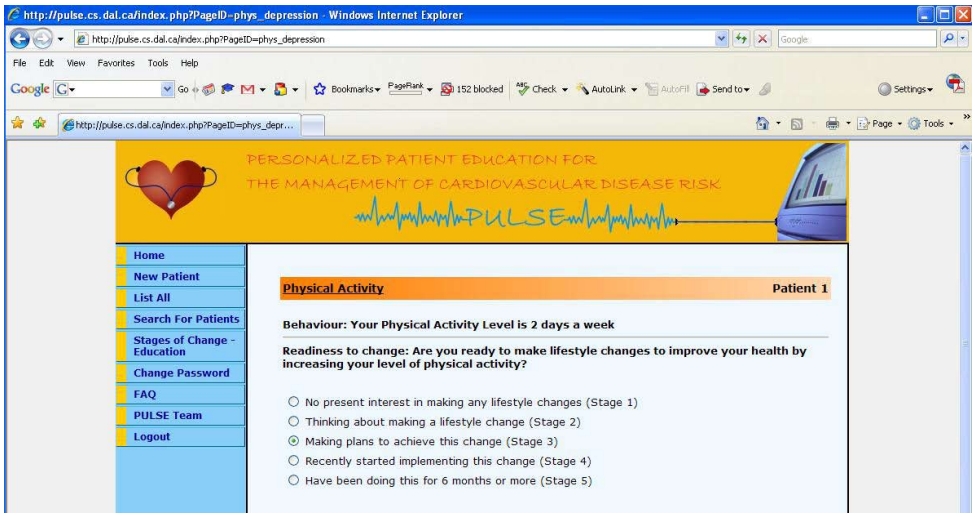

Figure 5. *PULSE system prototype: Patient 1 Input Data*

Patient 1 is a 48 year old diabetic woman with a Total cholesterol: High density lipoprotein cholesterol ratio of 4.3 , fasting plasma glucose of 6.3 mmol/L, and Blood Pressure of 135/88 mmHg. She is a non-smoker and has no history of depression. She exercises twice per week and reveals her readiness to change as '*Making plans to achieve this change*'. In this example, Patient 1's SCORE is 2% (Moderate). She receives 14 messages containing information relevant to her including: gender-specific information and exercise stage 3. Figure 5 shows a computer 'screen shot' of Patient 1's input data taken from the system prototype.

Patient 2 is a 60 year old hypertensive man with Total cholesterol: High density lipoprotein cholesterol ratio of 6.2, fasting plasma glucose 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 does not exercise regularly and a readiness to change this behaviour is expressed as '*No present interest in making any lifestyle changes*'. In this example, Patient 2'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.

Software testing is a process used to identify errors in computer programs and verify their ability to execute correctly and reliably. Like most software produced today, PULSE is modular and as such, system testing involves evaluating if there are any communication flaws between modules. In PULSE's case the software was specifically tested to see if the personalisation decision logic module was passing one or more messages to the display module for one or more risk factors of the given profile.

The logical argument for the system test stated that if any of the feature's test cases fail then the system test failed. The five test cases we initially tested in the test suite

failed on first execution of the PULSE system. In all cases, the same message tags were problematic. Corrections to the system were made accordingly and the test suite executed for a second time. On second execution of all test cases, no messages were missing or incorrect for the given profile and, as such, the PULSE system test was deemed to be satisfactory.

CONCLUSION

In Canada, there is a realisation that evidence-based standards for care are vital to effective health services. In the PULSE project we have proposed a computer-tailored patient education strategy for cardiovascular disease that features:

- Usage of SCORE for risk assessment
- Incorporation of behaviour change inputs in determining the educational content as opposed to just relying on medical data
- Usage of an evidence-based patient data capture template based on a model currently operational
- Leveraging Canadian clinical guidelines for both deriving the decision logic and the corresponding educational intervention
- Personalisation of educational material

The combination of these features contributes a novel solution that offers the functionality to support and deliver personalised Web-based patient education interventions for the management of cardiovascular risk. We believe that quality and timely patient-directed interventions can be combined into a healthcare service that can reduce disease risks and deal with risk management by influencing changes in patients' behaviours through the provision of up-to-date and pertinent lifestyle modifications and change strategies.

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