Approach to an ontology-based mobile intervention for patients with hypertension

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Abstract. Lifestyle changes and the adoption of healthy behaviours are well established recommendations for the management of hypertension, a risk factor for cardiovascular and kidney disease. Mobile health interventions offer unique advantages and novel approaches to helping individuals make and maintain such behaviour changes; however, current interventions often lack theoretical and scientific grounding. The objective of this study is to effectively model the knowledge, concepts and relationships relevant to the management of a chronic illness like hypertension, and to implement this knowledge model within a mobile self-management application that can be used by patients. A behaviour modification approach based on COM-B (capability, opportunity, motivation, behaviour) Model and the associated Behaviour Change Wheel (BCW) was developed. An ontology-based knowledge model was implemented to formally conceptualize relevant knowledge in hypertension clinical guidelines, behaviour change models and associated behaviour change strategies. In future work, a hypertension management decision support framework will be designed and implemented as a mobile phone application using the aforementioned model. The usability of this pilot application will be tested by patients with hypertension. This application which will create clinical and behavioural profiles of a user to provide them with personalized management strategies, rooted in established behaviour change theory, that will engage and empower them to manage their condition. Given the nature of ontological models, this approach can be easily modified to address a variety of chronic illnesses.

Keywords: Mobile health, Ontology, Hypertension, Chronic disease self-management

1 Introduction

Chronic disease places a steadily increasing burden on public health in the developed world. Chronic, non-communicable conditions are the leading cause of mortality worldwide, accounting for over 60% of all deaths in 2005 [1]. Hypertension specifically is the most common preventable risk factor associated with premature death worldwide [2]. Often symptomless, it places sufferers at risk of severe cardiovascular disease and chronic kidney disease.

Lifestyle changes and the adoption of healthy behaviours are well established recommendations for the management of hypertension [3]. In practice, however, initiating and maintaining these adjustments can prove difficult. Behavioural change models such

as social cognitive theory, the transtheoretical model, and the health belief model provide the theoretical footing for many strategies and techniques aimed to assist individuals with these changes [4]. These interventions based on theory and theoretical constructs have been demonstrated to be more effective than those that have no such basis [5].

Mobile application-based health interventions offer unique advantages for the management of hypertension and other chronic diseases. The most effective strategies are those that involve one-on-one interventions and ongoing assessment by clinicians or other health care providers; time and resource requirements hinder the practicality of these approaches, making them difficult to adopt on a large scale [6]. Mobile applications have the potential to employ continued monitoring of activities and behaviours and provide real time, dynamic feedback based on those data. In this way, an effective application could be able to provide dynamic, customizable self-management strategies to a wide population of smartphone owners without the time and resource burdens of frequent patient-provider interventions.

The unique advantages and novel ways to monitor and shape medicine and public health offered by mobile health (mHealth), along with the increasing ubiquity of smartphones, have helped make it a rapidly expanding and attractive field. Mobile interventions grounded in behaviour change theory have been shown to improve outcomes for patients with chronic diseases [6,7]. However, these theory-based interventions are in the minority, and mobile applications often only track data without helping to manage positive change [8]. This is due in part to the challenge involved in organising the enormous amount of information surrounding a chronic disease and its management in a useful and logical way.

One means of managing a large amount of data in a meaningful way is by conceptualizing it as an ontology. This type of knowledge model formalizes variables, properties, and relationships such that they can be used for problem solving. This current research proposes that, by integrating and computerizing complex knowledge from clinical practice guidelines, behaviour change theories, and associated behaviour change strategies, it is possible to model existing information about the management of hypertension as an ontology. A comprehensive model with the appropriate flow of content and information can then serve as an evidence- and theory-based knowledge source for a mobile self-management application. This proof-of-concept application will be tested for ease of use and for the comprehensibility of its content by individuals with chronic disease.

2 Research Approach

The abovementioned objectives are pursued through a health knowledge management approach that involves translation of paper-based CPG and behaviour change models, in terms of mobile decision-support tools that will (a) engage patients in their hypertension care process by generating a hypertension self-management program that takes into account their preferences, challenges and needs; and (b) Empower patient to self-manage their condition by providing them personalized educational and motivational

messages through a mobile hypertension self-management app. The theoretical foundation of our research is grounded in Behaviour Change Models (the knowledge content) and Healthcare Knowledge Management (the knowledge translation method).

This research has been separated into three distinct stages: 1) the development of an ontology-based knowledge model to formally conceptualize the relevant knowledge in hypertension clinical guidelines, behaviour change models and associated behaviour change strategies; 2) the design and implementation of a hypertension management decision support framework using the abovementioned knowledge model to deliver highly personalized, evidence-based recommendations and behaviour change strategies in order to help patients modify their behaviours; 3) the testing of the usability of this pilot application by patients with hypertension. This paper focuses on the development of the behaviour modification strategy and implementation of the knowledge model that integrates relevant knowledge sources with the health theory.

3 Methodology

A top-down approach was used for the development of the behaviour change approach and implementation of the computerized model based on this approach. A literature search was conducted to guide the selection of theories, models, and constructs surrounding behaviour change. The inclusion and integration of various models and their constructs was discussed with an expert in health behaviour psychology.

The COM-B Model [9] and the associated Behaviour Change Wheel (BCW) were chosen to serve as framework for the development of hypertension related behaviour change strategies. The BCW was developed through the synthesis of common features within multiple behaviour change frameworks that were identified in a systematic literature review. As seen in Fig. 1, at the core of the BCW is the COM-B Model. It posits that, for any behaviour to occur, there must be 'capability', 'opportunity', and 'motivation'. Each of these components can be further divided into two types. Capability can be 'physical' (having the physical ability, strength or stamina to perform a behaviour) or 'psychological' (having the knowledge and psychological skills or strength to perform a behaviour). Opportunity can be 'physical' (environmental influences like time, resources, location) or 'social' (interpersonal influences, social cues, cultural norms). Motivation may be 'reflective' (self-conscious planning and evaluation) or 'automatic' (deeper processes involving wants and needs, desires, impulses and reflex responses).

Changing the incidence of any behaviour of an individual, group or population involves changing one or more of the COM-B components. To accomplish this, the model defines nine intervention functions surrounding the central 'hub' which can be used to address and change the COM-B components identified. Intervention functions are broad categories of means by which an intervention can change behaviour. Behaviour change techniques can be classified based on the intervention function that they employ. In this way, the integrated framework provides a means of linking specific behaviour change interventions to the components of the COM-B model.

Fig. 1. The COM-B/Behaviour Change Wheel is one of several models which serve as the basis for the ontology.

The BCW model provides a systematic, scientific approach to selecting and applying behavioural constructs to intervention design. This model is also expandable, allowing for the integration of behaviour change strategies and constructs from other theories and models such as the Transtheoretical Model of Change [10], eHealth Behaviour Management Model [11], and Michie et al.'s behaviour change technique taxonomy [12].

Fig. 2 shows a concept map that was created to outline how clinical practice guidelines, behaviour change theories, and associated behaviour change strategies would interact within the ontology. A patient's clinical and psychosocial parameters will be used to create a personalized profile. This profile, along with input from the patient, will highlight the appropriate behaviour changes indicated as per clinical guidelines. To best assist the patient with these changes, the COM-B components of capability, opportunity, and motivation will be assessed. The BCW can then be used to link COM-B constructs with potential intervention functions. Individual behaviour change techniques serve as the basis for interventions to be delivered by the mobile application, and consist of a variety of messages, tasks, and resources. In this way, a patient is provided with directed interventions specifically chosen to address COM-B construct deficits, supporting behaviour change goals and resolving potential obstacles.

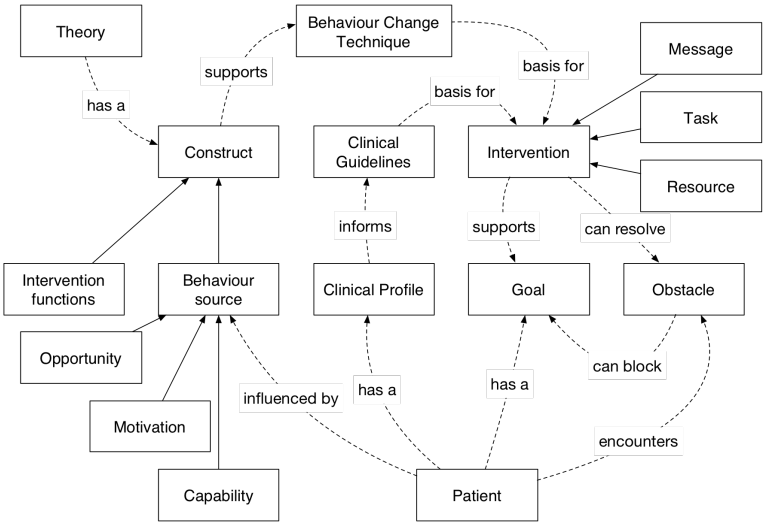

Fig. 2. Concept map outlining relationships between ontology model content.

In addition, a generalized process flow (Fig. 3) was designed to illustrate how relational information within the ontology will be organized and used to solve problems in the context of a mobile health intervention. The semantic nature of an ontology provides the flexibility and extensibility required to represent and assimilate complex health knowledge from a variety of sources while remaining logically sound.

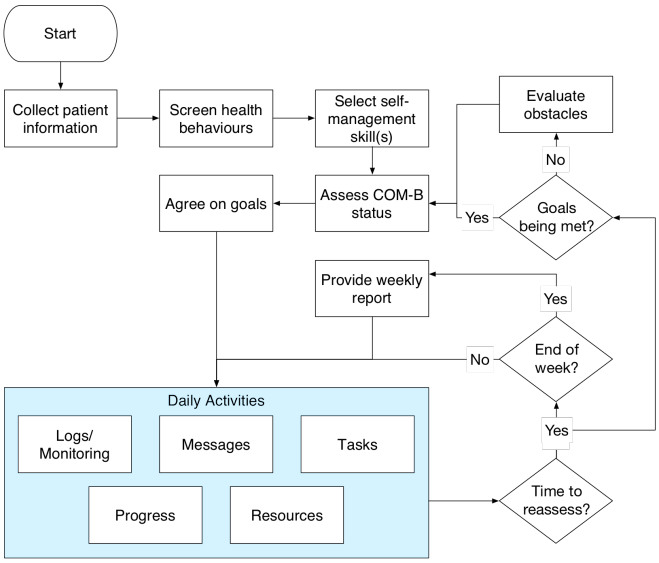

Fig. 3. Process flow demonstrating the movement of content and information within the proposed mobile application.

Once the theoretical underpinnings of the behaviour change strategy were established, the model was formalized and instantiated using a computational logic-based language (OWL Web Ontology Language [13]) and open-source ontology building software (Protégé [14]). Content from clinical practice guidelines, behaviour change theories, and intervention strategies was organized within classes of the model (Fig. 4). Content strategy was used to create and shape the flow of content and information within the ontology. Experts in cardiology and behaviour change psychology were consulted to provide insight and content validation, and to help model lifestyle and nutrition management change in keeping with behaviour change strategies.

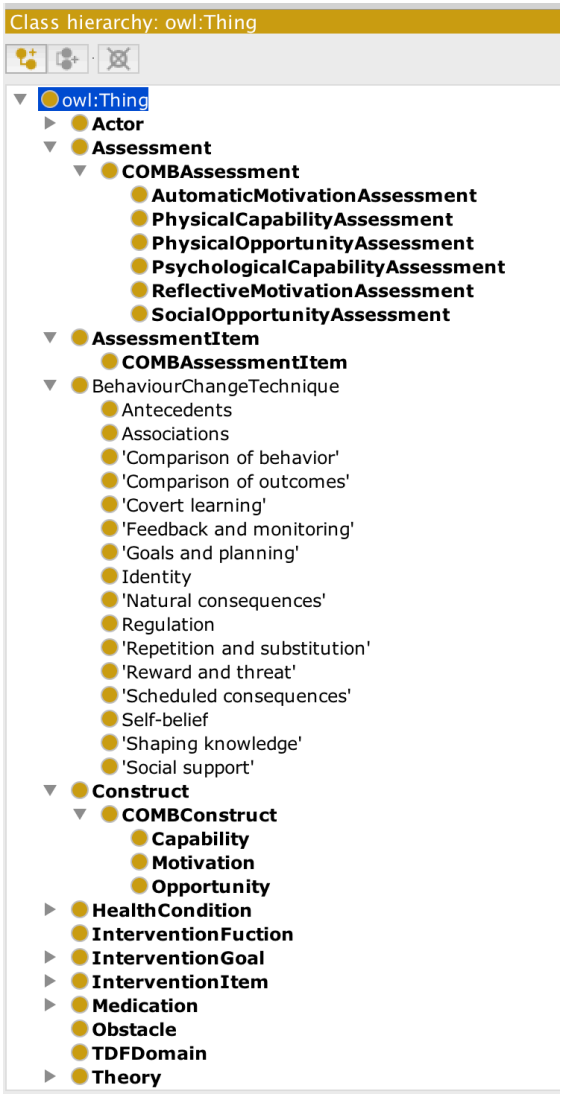

Fig. 4. Classes within the ontology knowledge model.

The salient classes in the ontology are presented as follows:

Actor refers to various individuals involved, in addition to the patient, that might assist the patient in self-management of hypertension, e.g. family physician, nurse, cardiologist.

COMB Assessment refers to the psychosocial assessment of the patient based on the constructs of the COM-B model. Each subclass within this class is operationalized by a set of questions which assess the contribution of each construct towards the desired behaviour.

Behaviour Change Technique represent various specific techniques that can be used to build a behaviour change strategy for a patient based on his/her behavioural assessment derived from COM-B constructs, medical profile and preferences.

The classes *Intervention Function*, *Intervention Goal* and *Intervention Item* represent various features of the behaviour change intervention that can be used to further tailor the intervention towards individual patient's profile.

4 Discussion

This current work represents the first steps in a larger project which will serve as a 'proof of concept' to demonstrate that it is possible to 1) effectively model the knowledge, concepts and relationships surrounding the management of a chronic illness and 2) package this model within a mobile self- management application.

The next stage in this research is to encapsulate the created ontology within a mobile application. Users will input health variables (e.g. age, weight, blood pressure readings) and answer questions derived from behaviour change models to assess behavioural factors (e.g. motivation to change). These clinical and psychosocial parameters will be used to create a personalized profile and accompanying self-management strategy. This strategy will consist of educational and motivational messages, notifications, and reminders, all while taking into consideration user-specific preferences, needs, and motivation to change (Fig. 5). All strategies will be grounded in the evidence-based models the ontology conceptualizes.

After completion, this proof of concept application will be tested for usability by recruiting a sample of 8–10 individuals with hypertension. Participants will be asked to work through reconstructed representative case scenarios and asked to perform a set of specified tasks as their interactions with the app are recorded. Pre- and post-questionnaires will also be incorporated. No personal health information will be collected, however information on demographics, socioeconomic status, and current use of technology will be collected and considered in the interpretation of results. This qualitative data will be analyzed using the grounded theory method.

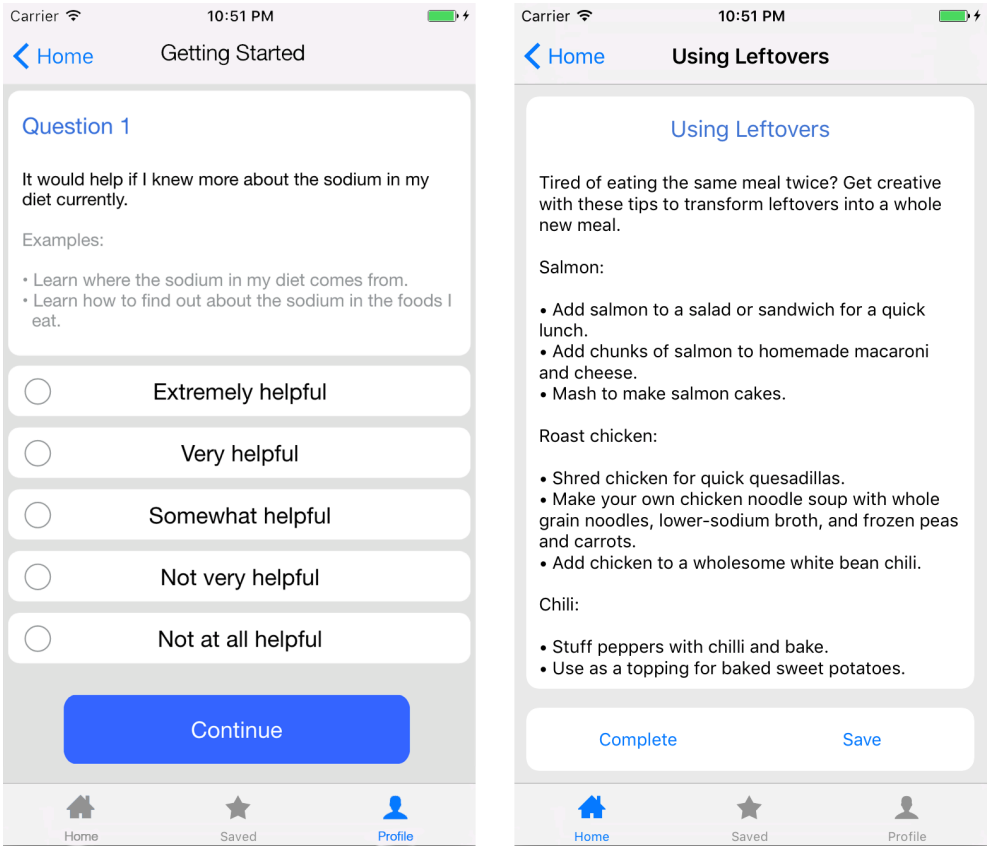

Fig. 5. Example questionnaire and tip message screens from in-development mobile application.

5 Conclusion

A health behaviour change intervention for a chronic condition like hypertension is well-suited for mobile adaptation due to the ability to provide real-time monitoring and dynamic, customizable feedback without the time and resource burden of one-on-one interventions and on-going assessment by clinicians or other health care providers. One issue that prevents many current mobile applications from successfully impacting behaviour is the inability to integrate and act on information provided. An ontology-based knowledge model provides a means to assimilating and organizing large amounts of information from a variety of sources, making it an ideal way to capture the complexities of managing a chronic disease such as hypertension.

If feasibility and usability are established, using hypertension as a model chronic disease, further research can be conducted to evaluate the efficacy of this pilot application as a self-management tool. Given the nature of ontological models, this approach can be easily modified to address a variety of chronic illnesses.

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