Patient and Provider Perspectives on Usefulness of a Computerized Behavior Modification Intervention in a Shared Decision Making Environment

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Abstract. *Objective*: To develop and evaluate a decision support platform called "Diabetes Web-Centric Information and Support Environment (DWISE)" that assist primary care practitioners (PCP) in applying behavior change strategies and clinical practice guidelines (CPG)-based recommendations to a patient and, empower the patient with the skills and knowledge to self-manage their diabetes through planned, personalized and pervasive behavior change strategies. *Methods*: Healthcare Knowledge Management approach is used to implement DWISE with the following functionalities: (i) Assessment of PCP's readiness to administer behavior change (BC) interventions to the patients; (ii) BC educational support to PCP; (iii) Access to evidence-based material, such as the CPG, to the PCP; (iv) Development of personalized patient self-management programs to help the patients achieve healthy behaviors; (v) Educational support for the patients; (vi) Monitoring the patients' progress in adhering to their BC program and motivating them to be in compliance with their program. DWISE offers these functionalities through an interactive web-based interface to PCP, whereas the patient's self-management program and behavior interventions are delivered through mobile patient diary on the smart phones. *Evaluation:* Focus group method was used to elicit shared and contrasting viewpoints, within and between health providers and patients, especially about potential use of DWISE in a shared decision making environment. *Conclusion*: This work has provided a unique e-health solution to translate complex healthcare knowledge in terms of easy-to use, evidence-informed, point-of-care decision aids for PCP and patients Results have been used to guide the modification of DWISE in terms of its design, functionalities and content.

Keywords: Ontology, Knowledge Modeling, Behavior Modification, Chronic disease self-management

1 Introduction

Canadian Diabetes Association (CDA)'s Clinical Practice Guideline (CPG) [1] suggests an interdisciplinary approach towards Diabetes management. Diabetes in Canada is generally managed by family practitioner (FP) in primary care clinics, and as well as by health providers such as nurses and dieticians qualified by the CDA as certified diabetes educators (CDE) in Diabetes Management Centers (DMC). Patients are referred to DMC by their FP. Patients at DMC are provided with self-management education and tools to help them self-manage their condition and associated risk factors. The Behaviour Change Institute (BCI) at Nova Scotia Health Authority (NSHA) in Halifax offers primary health providers (PCP) i.e. FP and CDE, training and support in working with patients who require assistance in modifying unhealthy behaviors patterns and support with self-management. Our group, through BCI, has developed specialized behavior change training modules that both train and empower PCP and patients living with diabetes to effectively use behavior change methods to better achieve clinical outcomes. Despite the availability of specialized behavior change interventions and evidence-based CPG on diabetes management, the challenge is to translate these knowledge resources at the point of care such that the PCP can use them to offer evidence-informed behavior change support and diabetes management to individuals with diabetes. Studies have shown sub-optimal and non-standardized diabetes care at the primary care level [2,3,4]. Given that there are too few behavioral support training opportunities and significant barriers to PCP uptake of intensive competency based training programs [5,6,7], and limited patient access to the DMC and the behavior change support [8], it is prudent to leverage technology-enabled mechanisms to deliver CPG-informed diabetes care and behavior change interventions to support PCP and patients in managing diabetes.

In this research we leveraged e-Health and Semantic Web technologies to develop "Diabetes Web-Centric Information and Support Environment" (DWISE) that features the following functionalities: (i) Assessment of PCP's readiness to administer validated behavior change interventions to patients with diabetes; (ii) Educational support to PCP to help them offer behavior change interventions to patients with diabetes; (iii) Access to evidence-based material, such as the CDA CPG, to the PCP; (iv) Development of personalized patient self-management programs to help patients with diabetes achieve healthy behaviors to meet CDA targets for managing type 2 diabetes; (v) Educational support for patients to help them achieve behavior change; (vi) Monitoring the patients' progress in adhering to their behavior change program and motivating them to be in compliance with their program. DWISE offers these functionalities through an interactive Web-based interface to PCP, whereas the patient's self-management program and associated behavior interventions are delivered through mobile patient diary on smart phones and tablets. We believe that Semantic Web based knowledge modeling and execution [9] can be aptly applied to translate diabetes knowledge resources in terms of point-of-care decision support and education resources for PCP. We used a focus group study to elicit shared and contrasting viewpoints, within and between PCP and patients about potential use of DWISE in a shared decision making environment.

2 Research Approach

The theoretical foundation of our research is grounded in Behavior Change Models in terms of the knowledge content [10,11] and, Healthcare Knowledge Management in terms of the knowledge translation method. The key research task pursed in this research is to build on the diverse clinical and behavioral knowledge sources and Semantic Web approaches to develop a behavior change program targeting both PCP and patients.

Our research approach is to incorporate Social Cognition Theory (SCT) [12], a validated health theory, to address an individual's self-efficacy expectations and perceived capabilities to learn or perform self-care actions. Self-efficacy attainment has been shown to influence an individual's motivation, accomplishments, self-regulation and efforts to perform self-care actions [39] and in turn has shown to improve clinical outcomes [13-16]. Based on the principles of SCT, our approach is to develop a specialized behavior change strategy that first assesses the physician's and patient's readiness to undertake behavior change interventions, and then in response to their readiness levels stipulate a personalized behavior change program. While there are many existing self-management programs that target patient's behaviors, a unique aspect of this research is assessment and enhancement of the PCP's readiness and self-efficacy (in addition to the patient) to manage behavior change in individuals with psychosocial barriers to change. We argue that better insight into the PCP's readiness and self-efficacy allows personalization of the relevant psychosocial and behavioral resources that will more likely improve the chances for PCP's success in managing behavior change in their patient.

We have pursued ontology-based knowledge modeling [17] to develop a behavior modification ontology (BMO) using Web Ontology Language (OWL) [18], a computational logic-based language, to develop our ontological model. An innovative aspect of this research approach is the modeling of the knowledge and workings of the BCI, CDA CPG based recommendations and behavior change strategy in terms of a common ontology-based knowledge model, thus enabling the translation of this specialized knowledge to non-specialists and patients. The integrated knowledge model entails (i) sections of the CDA CPG pertaining to the management of glycemic control; and (ii) elements of BCI's behavior change strategy including: (a) readiness to change assessments; (b) motivational enhancement interventions categorized along the lines of patient being ready, ambivalent, or not ready; and (c) self-efficacy attainment and self-management. The model is used to personalize information at two broad levels: (i) clinical level, where CPG derived clinical variables are used to tailor most relevant recommendation(s) for the given patient; (ii) behavioral level, where the behavioral variables derived from the relevant behavioral models.

3 Methodology

We have used METHONTOLOGY [19] framework for an ontology-based information system designed. This is a well-recognized and structured ontology engineering methodology that describes ontology life cycle and enables ontology engineering at the conceptual level, as opposed to the implementation level. Our implementation methodology for DWISE is described in detail as follows:

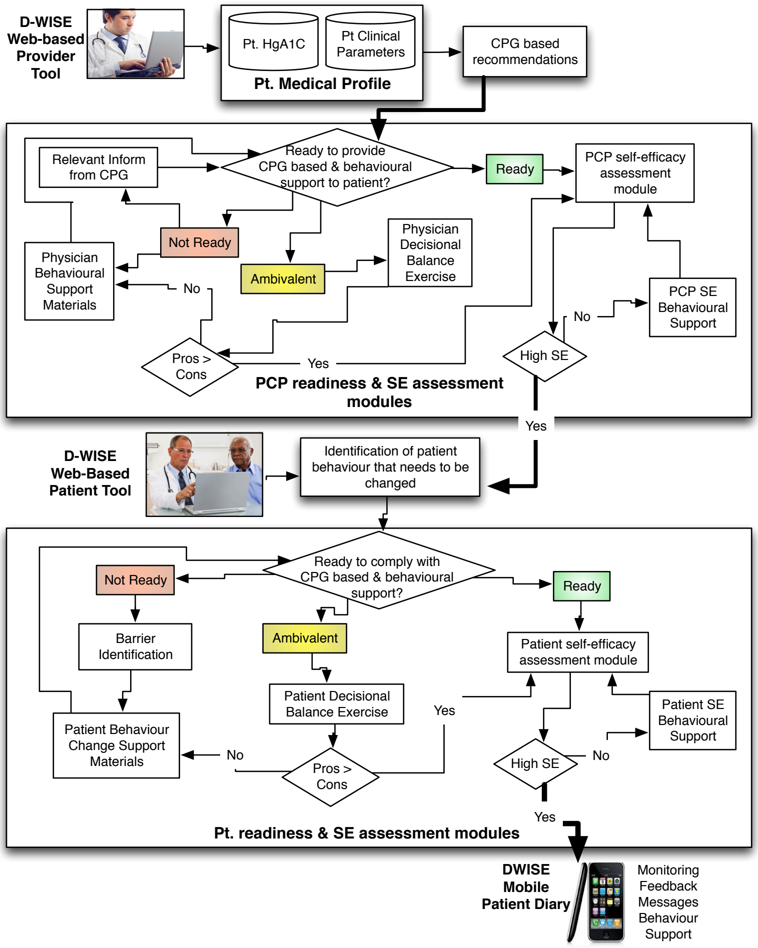

Figure 1: High-level Behaviour Change Algorithms for PCP and Provider

3.1. Knowledge Gathering and Abstraction

We began knowledge abstraction by identifying relevant behavioral determinants that might influence the diabetes related behavioral outcomes and used them to create theory-based behavioral profile. Given that behavior modification is a non-linear process, we have used behavioral determinants from multiple health behavior models and multiple levels/ranges of these determinants to capture non-linear nature of behavior modification. Two high-level behavior change algorithm (Fig. 1), one each for PCP and patient have been developed. Each algorithm highlights assessment tools based on relevant behavioral determinants, range of PCP and patients' inputs, key steps and the sequence in which behavior change strategies are to be administered, and the subsequent system responses and corresponding educational material. The algorithms are based on three behavior change models described as follows:

Readiness Assessment behavior model is developed by our team at the BCI. This model when used in the provider tool assesses the readiness of a PCP in providing self-management and CPG based support to the patient to help him/her modify a given behavior. When implemented in the patient tool, the model measures the readiness of the patient to comply with the self-management support provided. Readiness assessment model places an individual into 3 stages of readiness to change behavior, i.e. Ready, Ambivalent and Not Ready. Readiness is measured with the help of a simple questionnaire with responses ranging from 'yes', 'no' and 'maybe' corresponding to 3 stages of readiness. As in other stage models, e.g. Transtheoretical model [20], movement between stages in Readiness Assessment model is non-linear and dependent on levels of motivation and self-efficacy that can be expedited by usage of cognitive and behavioral processes. In order to address the non-linear progression in behavior change, two more behavior models, i.e. a Decisional Balance measure and a Self-Efficacy assessment are included.

Decisional balance measure is included to determine an individual's perceptions of the expected benefits (pros) of modifying a behavior as appose to the disadvantages or costs (cons) of this behavior modification. An individual who is ambivalent or not ready must undergo a decisional balance assessment. Decisional balance assessment includes up to 5 pros and 5 cons that measures positive and negative perceptions of health professionals in providing self-management support and of patients in adopting self-management behaviors. A second round of readiness assessment follows the decisional balance exercise, in order to identify any improvement in level of user's readiness.

Self-efficacy assessment of individual who are 'ready' is carried out towards the end of the behavioral assessment. Self-efficacy measures a 'ready' provider's degree of confidence that he/she can support patient in modifying target behavior and, a 'ready' patient's degree of confidence in receiving behavioral support and in complying with subsequent behavioral modification program.

The provider algorithm (Fig. 1) begins with applying CPG based recommendation(s) to a patient based on patient's clinical profile that comprises of the CPG based variables. The provider then undergoes readiness assessment, decisional balance exercise and self-efficacy assessment. A number of resources such as evidence from the CPG, support material to help provider determine most suitable target behavior for the patient and behavior support for the providers are tailored based on outcomes of patient clinical profile and provider's behavioral assessments. The patient algorithm (Fig. 1) than follows logically from the provider algorithm, beginning with the target behavior for the patient that needs to be modified in order to successfully achieve the target Hg A1C level as recommended by the CPG. The patient algorithm, also contain specifics about the strategy that would be used to overcome a given behavior in terms of time, location, frequency, barriers to change and assistance in goal setting using SMART (Specific, Measurable, Action-Oriented, Relevant, Timely) criteria.

3.2. Knowledge Modeling

We have employed Ontology Modularization [21] principles towards ontology engineering to minimize cognitive burden and complexity introduced by the integration of psychological theory with domain knowledge such as Diabetes CPG content, self-management and behavior change support materials. Ontology Modularization [21] involves generating smaller ontological units that are self-contained and representative of a specific domain area; nevertheless have definite relationships with other modules. This approach is considered as best practice in current ontology engineering and Semantic Web movement [21]. Ontology engineering methodology involving cyclical iterations of knowledge acquisition, model design, implementation, and evaluation by experts is used to construct each module within the ontology. Ontology Modularization, by reducing the complexity, ensures efficient reasoning [22]. All the ontological modules within BMO (Fig. 2) are constructed using Methontology [19]. The ontology has been evaluated for: (a) knowledge accuracy by domain experts (psychologist endocrinologist and a family physician,); and (b) semantic accuracy to ensure logical consistency [23].

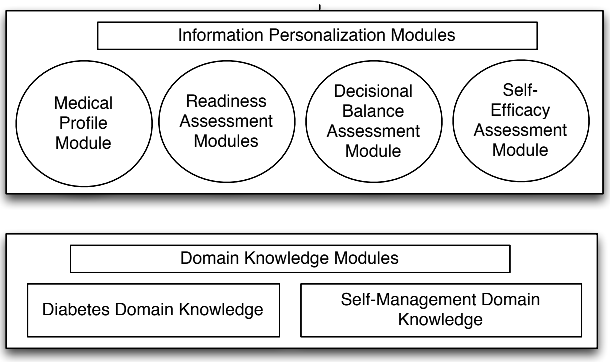

Figure 2: Information Personalization and Domain Knowledge elements of BM

Behavior Modification Ontology (BMO) Engineering. Protégé 2000 was used to implement the ontology, with OWL as the underlying representation language [24]. In accordance to ontology modularization approach we created BMO in two main ontological modules (Fig. 2):

Information Personalization Module to create unique patient profiles and consist of three sub-modules:

- Medical Profile Module based on the variables derived from the CDA CPG that represents patient's clinical profile and allows medical data collection and subsequent tailoring of the CPG recommendations.

- Readiness Assessment Module (Fig. 3) that represents readiness assessment strategy developed by our team at BCI.

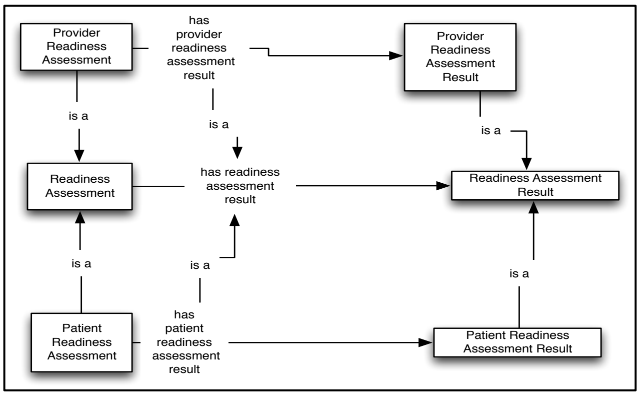

Figure 3: A subset of Readiness Assessment module in BMO, depicting procedural relationships between classes "Readiness Assessment" and "Readiness Assessment Result"

- Decisional Balance Assessment Module that measures positive and negative perceptions of health professionals and patients who are not ready or ambivalent in providing and receiving self-management support respectively.
- Self-efficacy Assessment Module that in accordance to the SCT assesses the self-efficacy of the provider and the patient in providing and receiving self-management support respectively.

Domain Knowledge Module that is used to represent the domain knowledge and comprises of two sub-modules:

- Diabetes Domain Module that represents evidence based recommendations in the CPG
- Self-Management Domain Module that represents self-management domain knowledge, e.g. barriers to diabetes self-management and behavior change, self-management and behavior change support materials and strategies, and goal setting support.

The patient profiles are created dynamically during execution of the personalization module. The two main modules within BMO are integrated once a profile is created. This occurs during the execution at the point of use; whereby highly targeted diabetes management messages and strategies are provided to the physicians and patients. We used object properties to represent declarative (spatial) and procedural (temporal) relationships between classes. Using rules further augments the procedural aspect of the BMO.

Personalization modules such as Readiness Assessment, Decisional Balance Assessment and Self-Efficacy Assessment required enactment of questionnaires to identify patient's current behavioral predilection. Questionnaires are represented as an object, and the questions within them as properties. Questions that require a small range of allowable values, e.g., 1 to 4, are represented as datatype properties, while questions that require proper representable knowledge content as a response (e.g. What is the highest level of education you have achieved? with possible responses: Graduate, Undergraduate, High-school, Less Then High school) are represented as object type properties. This approach towards representation of questionnaires is deemed effective and reliable, since property restrictions, such as cardinality restrictions, range (both for object type and data type) and allowed values are used to ensure data integrity. Moreover, each instance of a patient or a provider is related to each instance of each questionnaire, thereby providing all required data on an individual for information personalization. Finally, BMO is instantiated using the content that was gathered and developed in the two algorithms (section 3.1).

3.3. Evaluation of Behavior Modification Ontology (BMO)

BMO has been evaluated for domain accuracy, core competency and usefulness by the domain experts (a psychologist, an endocrinologist and a family physician) using open source graph visualization software called Graphviz [25]. The OntoViz tab in Protégé [24] allows visualization of Protégé ontologies with the help of Graphviz. Changes were made to BMO in terms of its concept description, relationships and constrains after each evaluation event in response to the experts' comments and case notes that were agreed upon by all three experts. The technical evaluation of BMO was carried out in accordance to the criteria suggested by Gomez Perez [23], which include the three Cs: Consistency, Completeness and Conciseness. FaCT++ [26] an open-source OWL DL reasoner was used to perform the subsumption tests on the ontology to establish its concept satisfiability and consistency. Fact++ was also used to compute the inferred class hierarchy and to identify redundant arcs between the classes. Our classification tests did not show any redundant arcs in the ontology, therefore it is concluded that the asserted hierarchy is similar to the inferred hierarchy. Finally, BMO, in terms of necessary and sufficient conditions of a predicate, domain and range of relations, generalization and specialization of classes, demonstrated representational capacity to adequately instantiate the relevant domain concepts, relationship and constrains captured in the BM algorithms and CPG content

4. Implementation of DWISE Decisions Support Framework

A prototype of the DWISE framework consisting of Web-based patient and provider tools has been implemented. Extended client-server architecture and Web services have been used to distribute the functions of the system and to make it operational in limited connectivity conditions. In addition to the Web-based implementation, a diabetes messaging and monitoring app for the patients has also been developed that can be accessed through their mobile devices such as smart phones and tablets. The actual web application is written in Java and Vaadin and information is stored in a secured relational database on a centralized server. The database is implemented using MySQL. Within DWISE, BMO serves as the main knowledge resource capturing all the necessary knowledge needed for educating PCP, and engaging patients. Protégé-OWL programming library, an open-source Java library for the OWL and RDF is utilized on the server to read and manipulate the domain knowledge contained in. owl files. The decision rules are translated into JENA rule syntax that are input into to the JENA reasoning and inference system. JENA uses the rules and temporal relations specified in the BMO to integrate ontological modules during execution of the BMO to infer information based on individual profiles.

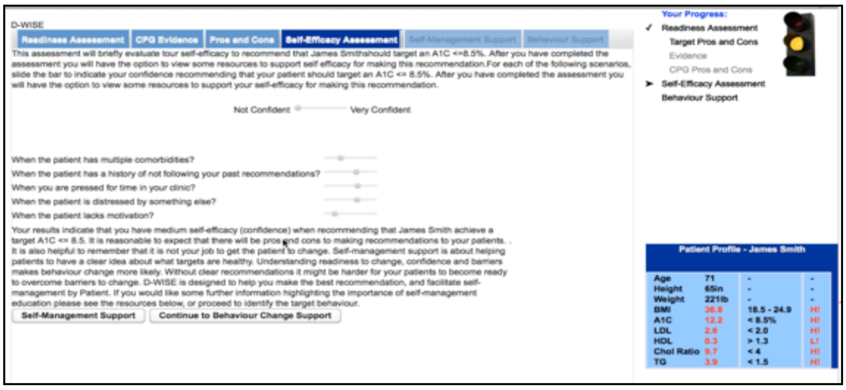

Figure 4: Provider tool assessing self-efficacy of the FP/CDE

5. DWISE Decisions Support System

DWISE is a web-based decision support framework that consists of a provider (PCP) and a patient tool. DWISE provider tool (Fig. 4) offers access to the recommendation(s) from the CDA CPG (e.g. most appropriate target A1C for a patient) that is highly tailored towards the clinical profile of the patient for whom behavioral support is being sought. It then assesses the readiness and self-efficacy of the PCP in supporting the patient achieve the CPG stipulated target and offers the PCP personalized behavioral support based on her own readiness and self-efficacy to help the patient modify harmful behaviors. Once provider is identified as being ‘ready’ by the tool, it enables the PCP whilst engaging with their patients in a shared decision making setting to develop a personalized behavior change strategy, akin to behavior change consultations performed at the BCI. The strategy is tailored towards an individual based on his/her behavioral profile that is developed through a series of behavioral assessment exercises administered through DWISE in a share decision-making setting. DWISE patient tool is implemented as both a Web-based system and a mobile app, is designed to deliver the following self-management support directly to the patient: (a) behavior change strategies such as: goal setting, behavior shaping, stimulus control and reinforcement management; (b) context-aware motivational and behavior change educational messages; and (c) communication with care providers. In addition to the above-mentioned functionalities, the DWISE mobile app includes a patient diary for capturing vitals, diet, exercise, stress and mood and in turn it provides proactive alerts and reminders to help patient adhere to their self-management strategy.

6 Implementation of DWISE App

A patient-centered DWISE mobile app has been development. The goal of this app is to support the patient to enact the self-management plan that he/she has formulated with the PCP using the Web-based patient tool, thereby promoting self-management in home based setting. The app encompasses: (i) patient diaries for capturing vitals, diet, exercise, stress and mood; (ii) proactive alerts to underline stimulus control and reinforcement management; (iv) context-aware motivational and behavior change educational messages and reminders to help patient adhere to the self-management schedule; (v) communication with care providers. The app has been developed for the Android platform using necessary data security and privacy regulations, with provisions for a future iOS based app.

7 Evaluation of DWISE

A qualitative descriptive design using the focus group method was used to elicit shared and contrasting viewpoints, within and between health providers and patients, especially about potential use of DWISE in a shared decision making environment.

6.1. Study Design

A purposive sampling strategy was used to recruit the patients and the PCP, after acquiring the ethics approval. We recruited 7 participants in the focus group, with 3 CDE and 4 patients. The focus group session last 120 min. The session was audio recorded and transcribed verbatim, and was supplemented by field notes, sketches and observation logs. The researcher experts on the team prepared a semi-structured moderator's guide based on their clinical and research experience and the review of the related literature. The guide included open-ended questions and problem-based representative scenarios related to various self-management processes, to stimulate conversations in cases of unresponsive participants. Content validity of the guide was established by review of the literature on diabetes self-management in populations that are culturally and socio-economically similar to the population of interest. Further validity was established through critique, modification and consensus of the expert research team members.

Participants were administered an informed consent and were asked to sign a consent form before the focus group session. The session was moderated by a team member with expertise in designing and administrating diabetes related behavior modification techniques, and previous experience in conducting this type of research. A research assistant assisted him in conducting the focus group session. Participants were provided with 10-15 minutes demonstration of the DWISE framework that highlighted various functionalities of DWISE, its information content, workflow, as well as screen layout and design features. Following this the focus group session per se commenced. The moderator encouraged participation of all members in the discussions using open-ended questions and prompts focusing on the: (1) initial impression about the DWISE system, (2) advantages and disadvantages of the DWISE in providing CPG based recommendation and behavior change strategies to the PCP and patients, (3) potential impact of DWISE on patient-provider communication and relationship when providing behavior change support to patients with diabetes (4) suggestions to improve the DWISE. Interview questions were reviewed as the study progressed to seek further clarifications.

6.2. Data Analysis

Transcribed verbatim, field notes and observation logs were uploaded to qualitative data analysis software called ATLAS.Ti. Data was analyzed using inductive thematic coding [27] method, using two steps: (i) open coding, i.e. tentative labeling of chunks of data; (ii) axial coding, i.e. identifying commonality and relationships in open codes. Unit of analysis was a quotation. In all we discovered 72 quotations in the data. Each selected quotation contained at least one or more open code. ATLAS.Ti also calculated code frequency, i.e. number of quotations to which a particular code is applied. Larger number of quotations associated with a quote indicated strong evidence found for this quote, which in turn endorses the groundness of that code in the data.

In order to perform thematic analysis, *a priori* categories (Table 1) based on the open-ended questions in the moderator's guide were established. During data analysis, the open codes assigned to the quotations were classified as axial codes based on their commonality. The axial codes were constantly compared against *a priori* categories listed in table 1 and assigned to one or more of these categories.

Table 1: A Priori Categories

	A Priori Categories
1.	Barriers to DWISE usage
2.	Facilitators to DWISE usage
3.	Patient Behavior modification
4.	Patient empowerment and education
5.	Patient autonomy and preference
6.	Patient-provider communication
7.	Encounter related issues
8.	Professional roles and responsibilities
9.	Usability/acceptability related issues

Validation of the identified open and axial codes was performed by continual referral back to the original transcripts, audiotapes and observational notes. Furthermore, another researcher on the team reviewed the data, so that any conflicts or discrepancies were resolved through discussion and consensus before the codes were finalized.

7. Results:

7.1. Participants

There were 7 participants, i.e., 3 certified diabetes educators (CDEs) and 4 patients. All three CDEs were female and out of 4 patients 3 were female and one was male. Ages for CDE ranged from 29-55 years and for patients ranged from 49-64 years. All CDEs worked at diabetes management centers. CDEs had a median of 11 years of experience (range 3 – 19 years). Patients had diabetes for a median of 13.5 years (range 2-25 years).

7.2. Principle Finding

In all 73 open codes were discovered in data that were classified into 27 independent axial codes. Table 2 shows the *a priori* categories and axial codes assigned to these categories. The number in parenthesis next to each axial code indicates number of open codes contained in each axial code, thereby indicating groundness of each axial code in the data. These categories are explained in an integrated manner that is from both patient and provider's perspective.

Facilitators to DWISE Usage. The PCP appreciated that DWISE can be used as a teaching tool to teach Diabetes related self-management skills to their patients. "I try to guide my patients towards diabetes related self-management resources available…. but really, there are silos of teaching that affects one's ability to learn. DWISE is good…. it is more comprehensive and is more relevant to a patient's needs … this can help deal with these problems … I believe this should be accessible to most patients".

The participants felt that although there are many diabetes educational resources, they want DWISE type apps that consider a patient's personal preferences and psychosocial concerns when designing self-management strategies. Both patients and providers felt that there is more need for information about the psychological issues for patients with diabetes. "There should be apps that talk more about things like…distress, depression and psychology… I mean diabetes is hard …. sometimes we are distressed …. we need information and we rely a lot on Internet… but DWISE is more relevant". Finally, patients that were more engaged in their self-management felt that DWISE is an ideal tool for them and they believe that engaging with DWISE will be easier for them. Participants overwhelmingly stated that they would like some kind of technical support, such as on-line or face-to-face sessions on DWISE, to teach them how to use DWISE. They suggested that there should be a help-desk or other resources to help them trouble shoot to facilitate use of DWISE. In general participants felt that DWISE has potential to improve diabetes related self-management and monitoring, and patient-provider communication.

Table 2: Axial Codes in each Category. Numbers in braces indicate number of open codes contained in each axial category.

A Priori Categories	Axial Codes
Facilitators to DWISE usage	Technical support to facilitate DWISE usage (10)
	Teaching tool for patients (5)
	Need for personalized diabetes self-management apps (4)
	Need for information about psychological issues (2)
	Compliance with DWISE easier for engaged patients (1)
Barriers to DWISE usage	Practicality of DWISE due to provider time constraints (4)
	Impact on patients who fail to achieve DWISE set goals (4)
	Age related suitability (4)
	Practicality of DWISE due to technically challenged users (3)
	Preference for direct patient-provider contact (3)
	Additional work (1)
	Liability related issues (1)
Patient Self-Management	Potential to improve self-management and monitoring (3)
	Potential to modify behaviour (1)
Patient education	Teaching tool for patients (5)
	Potential to improve patient awareness of disease (3)
Patient autonomy and preference	Patient autonomy in choosing self-management support delivery method (4)
	Power dynamic between patient and provider (2)
	Potential to improve patient empowerment (3)
Patient-provider communication	Insight into patient's self-management practices (2)
	Potential to improve patient-provider communication (3)
	Preference for direct patient-provider contact (3)
Encounter related Issues	Impact on patient provider encounter (3)
	Practicality of DWISE due to provider time constraints (4)
Professional roles and responsibilities	Professional roles and responsibilities around DWISE usage (2)
	Additional work (1)
Usability/acceptability related issues	Reminders to improve usability (1)
	System feedback (2)
	Information presentation in DWISE (2)
	Integration with other devices (2)
	Need for personal features in DWISE (3)

Barriers to DWISE Usage. From PCP's perspective, a key barrier to the use of DWISE was time constraints. The PCP felt that inclusion of DWISE based intervention might not be feasible during the encounter with the patients due to the limited time that they have with the patient. "I love it…but can I do a good job with it? …. how can I incorporate this within the time restrictions? …. at times it may not be conducive to my schedule –a patient gets just 15 minutes with the provider" **.** PCP were also worried about liability related issues. "Ok, suppose I am using this app with my patients, what if I missed something or I fail to do what is expected of me? would I be liable …. what will be the impact?" PCP also fear that including DWISE in their practice might result is additional work for them.

Patients were worried that if they fail to achieve the goals that they have set though DWISE, they might lose respect in the eyes of the PCP, or disappoint them, and might feel burdened or stressed. "I mean respect is a two-way street …. What if I don't meet that goal…. what would my doctor think about me?". Patients also stressed on preference for direct patient-provider contact. "Sometimes I just want to talk during an appointment with my doctors…. maybe I don't want to talk through an app during this time". Both PCP and patients felt that technology ineptness might be a deterrent to the use of DWISE. "One of my colleague is not tech savvy…. there might be other providers like her. How can these people benefit from DWISE? … would they be interested?" (Provider). "I am not technologically adept, these are new and exciting …. I like help with managing my diabetes….but there might be big learning curve for me" (Patient).

Patient Self-Management. Participants felt that DWISE has Potential to improve diabetes self-management, specially that smart phones are ubiquitous and self-management plans formulated through DWISE can easily be integrated in patient's lives. Participants indicated that DWISE has potential to improve diabetes related monitoring. "Phone is ubiquitous, so more opportunities. I love apps for recording and monitoring …this can help me monitor my sugar" (Patient). "It helps me gain more information about diabetes related behaviour change and about my patient and both my patient and I can see if my patient is on the right track…. we will have something to talk about next time we meet" (Provider).

Patient Education. Participants felt that DWISE help improve patient's awareness of the disease and can be used as a teaching tool for the patients. "DWISE makes me more aware …. more informed… I feel like I want to know more so that I can better take care of myself".

Patient Autonomy and Preference. Patient felt that they should have autonomy in choosing self-management support delivery method. "I don't believe that one size fits all… it is good to have platforms like apps …DWISE is easily available… it should not be made mandatory for every patient …. I mean it has to be my choice".

Patient also stated that DWISE has potential to improve power dynamics between patient and provider and help patient gain more control over their diabetes management. "I feel balance of power is always in favour of my doctor… it's not bad…but I like to be more involved…make decisions that fit my life … DWISE can give me more control". In general, participants felt that using a tool like DWISE might make them feel more empowered.

Patient Provider Communication. In addition to appreciating that DWISE has potential to gain insight into the patient's self-management practices the providers felt that DWISE could improve communication between patient and provider around Diabetes related self-management. "When a patient is first diagnosed with diabetes…DWISE can be a good avenue for discussion…about how a patient is feeling, what is it they want … how can they fit the self-management in their lives" (provider). Patients also felt that DWISE can potentially help them to communicate personal issues that might affect their self-management practices and that otherwise wouldn't come up during an appointment. "Doctors don't live with diabetes…I live with diabetes…I have lived with diabetes so long…this type of technology and apps can support me to better communicate with my doctor…what I am going through…why I am not able to follow proper diet or …not exercising…"

Encounter related issues. While some providers expressed that it might not be practical to use DWISE during the encounter due to provider's time constraints, other providers and patients expressed that DWISE can have positive impact on the patient-provider encounter. Providers underscored that a patient might be more prepared during the encounter. "Every patient is different …...and self-management requirements vary so much…. so patients coming prepared will be so good for the appointment …I think appointment time will be better spent ". The patients expressed that they will be more motivated to comply with plan set through DWISE to have a meaningful encounter. "There are higher problems that are not in my control… that might mix the schedule…. but I will still try to do this or change it to have a better appointment…. I'll go to the appointment with something…."

Professional roles and responsibilities. Providers were unsure about the professional roles and responsibilities around DWISE usage. They wondered how would doctors, CDE and nurses coordinate and collaborate to ensure that a tool like DWISE can be utilized effectively. "how would this work… I mean how do we collaborate… should this be administered through a doctor or a nurse educator… who would monitor."

Usability/acceptability related issues. Finally, participants offered some feedback regarding issues related to the usability and acceptability of DWISE. While some participants suggested that that there should be more reminders to help them comply with self-management plans and upcoming activities, others suggested that a user should be able to shut up the reminder when he/she feels like. Participants commented on the information presentation in DWISE, and suggested that too much text and explanation should be avoided and replaced by other user-friendly features such as pictures and figures and, better lay out. They suggested that a good feature would be to have a sidebar for users to type in their notes in free text, as they seem fit. The participants expressed their desire to have some personal features included in the app. These ranged from being able to include their "profile picture", to their "personal profile information", to their "personal diabetes story". The participants suggested that DWISE should be integrated with other data collection devices, e.g. fitbit.

4 Discussion

E-Health technologies have been effectively used for health information collection, information utilization and sharing solutions. E-health applications can incorporate evidence-based healthcare knowledge to provide evidence-informed decisions. This is ongoing work and DWISE is a proof of concept. Nevertheless, this work has provided a unique ontology based solution to translate complex healthcare knowledge—i.e. guidelines, clinical workflows, behavior models, educational content and long-term care plans—in terms of easy-to use, evidence-informed, point-of-care decision aids for both care providers and patients. From a clinical standpoint, the contribution of this research is the translation of specialized behavior change knowledge to family physicians and diabetes educators, thus enabling them to offer behavior change interventions to a larger population of diabetes patients—at present only one third of Canadians with diabetes receive diabetes educational programs [28]. From the patients' perspective, the contribution is a self-management program that engages and empowers them to manage their condition in a home-based and primary-care setting as opposed to specialist clinics. The unique aspect of this research is the demonstration of the synthesis of paper-based medical knowledge, behavior change models, healthcare knowledge management methods and mobile technologies to develop 'intelligent and adaptive' Web-based and mobile patient-centered solutions that are customizable to specific care contexts, users' knowledge and interests. The project has contributed a generic e-health strategy and technology, based on theoretical models, that can be applied to a range of medical conditions to deliver intelligent and ubiquitous health educational and decision aids. In the long-term we plan to extend the research to other chronic diseases where we will account for different disease-specific contextual factors. In the medium-term, we would augment the research scope to incorporate other related metabolic conditions that are characterized by hyperglycemia such as prediabetes. The focus group participants identified barriers and facilitators to the use of DWISE in shared decision-making settings and impact on encounter and, patient-provider relationship and communication. Most common barrier from provider's perspective is time constraints during an encounter and, from patient's perspective is fear of failure to achieve the goals that they have set through the DWISE. In terms of facilitators, the PCP identified the potential of DWISE as a teaching tool for their patients, and patients appreciated that DWISE provide personalized information especially on psychological issues that could be very useful to them. In general participants felt that provision of technical support, especially to elderly users and those who are not proficient in technology will facilitate the use of DWISE. Patients preferred that DWISE should not be made mandatory and should not completely replace direct interactions with the PCP, rather should be regarded as an additional support mechanism. Patients felt that DWISE may help them gain more control over their diabetes management, while providers suggested that it could assist them gain more insight into a patient's self-management practices. PCP seemed unsure about their respective roles and responsibilities around DWISE usage. A tool like DWISE that integrates a patient's psychological disposition with best evidence and SM strategies, when used in shared decision-making environment has potential to improve self-management and increase sense of collaboration and trust in care process. Our finding suggests a dynamic interplay of patient, physician, systemic and technology factors in the DWISE based diabetes management. However, implementation of DWISE like framework in shared decision making environment in primary care setting requires time, technical and organizational support and clear definition of professional roles and responsibilities. Data collected will guide changes to stages of the DWISE framework directed at both patients and providers. We realize that this is a pilot study with a small sample size and all CDE in terms of provider participants that limits the generalizability of this study. In the next stage, we plan to clinically evaluate D-WISE for its effectiveness and safety in primary care settings, with the intent to disseminate it across the province of Nova Scotia.

5 Conclusion

In this paper, we have presented a digital health solution to translate complex healthcare knowledge—i.e. guidelines, clinical workflows, behavior models, educational content and long-term care plans—in terms of easy-to use, evidence-informed, point-of-care decision aids for both care providers and patients. The knowledge modeling methods and decision support technologies being developed are both scalable and generic in nature, such that they can be readily applied to computerize CPG for other chronic diseases to develop low-cost decision support aids that can standardize the care of chronic diseases and co-morbidities at primary care. We tested DWISE for its usefulness and acceptability in a shared decision-making environment. Most common barrier to its usage from the provider's perspective is time constraints during an encounter and, from patient's perspective is fear of failure to achieve the goals that they have set through the DWISE. In terms of facilitators, the PCP identified the potential of DWISE as a teaching tool for their patients, and patients appreciated that DWISE provide personalized information especially on psychological issues that could be very useful to them. In general participants felt that provision of technical support, especially to elderly users and those who are not proficient in technology will facilitate the use of DWISE. Patients preferred that DWISE should not be made mandatory and should not completely replace the direct interactions with the PCP, rather should be regarded as an additional support mechanism. Patients felt that DWISE may help them gain more control over their diabetes management, while providers suggested that it could assist them gain more insight into a patient's self-management practices. PCP seemed unsure about their respective roles and responsibilities around DWISE usage.

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