Towards Semantic Models for Profiling and Behavior Change in eHealth Applications

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Abstract. Behavior change is a complex process in which people receive support in order to improve aspects of their behavior, for instance regarding their health or lifestyle. Although there exist several theoretical approaches to model behavior change, including abstractions that can be applied to different use-cases, these are not easily translated into reusable components that can be integrated into implementable systems for persuasion. This work discusses the need for an ontology-based approach to modelling interactions in eHealth systems, with the goal of achieving behavior change. This contribution includes an analysis of current modelling needs in behavior change, specially regarding: stages of change, motivation & ability factors, plans & actions, argumentation, and domain modeling.

1 Introduction

Improving quality of life and reducing health risks are increasingly important concerns in our society. In different situations, including the presence of chronic diseases, or the desire to adopt healthier daily habits (e.g. concerning diet, physical activity, etc.), these improvements are only possible if an effective behaviour change is also produced. This change can span from small alterations to daily routine to radical changes in lifestyle. It has been shown that personalized interventions are crucial in order to maximize the efficacy of behaviour change. Custom and tailored programs are nowadays feasible, thanks to advances in personal data analytics and personalized digital health. Different models exist to describe behaviour change strategies [3, 2, 1], and different technological solutions (e-Health, mHealth, serious games, reminders, chatbots, social networks) have been developed in several use-cases (diabetes, smoke cessation, overweight, active-ageing, rehabilitation, re-adaptation, etc.).

However, the effort required in order to adapt these models to the appropriate technologies in a given use-case, remains prohibitive and leads to ineffective or partial implementations, with little or incomplete personalization. As a consequence, there is no clear methodology that allows to effectively model the profile of a patient, with the goal of using artificial intelligence (AI) techniques to adapt

and personalize treatments, recommendations, and other health-related interventions. Therefore, even if different digital solutions and AI techniques have been shown to provide significant improvement to personalized treatments, it remains challenging to reuse and apply these methods to other use cases, or to establish a well-defined workflow for enabling tailored behavior change.

In this paper, we envision an ontology-based approach that establishes in a systematic way the different elements that can guide the implementation of personalized behavior change programs, using ontological models as a foundation layer. In concrete, we address: (i) the modeling of behavior change models themselves, i.e. the different states of a user, and the factors and barriers that have an effect on their actions; (ii) the modeling of arguments that can be used to persuade or to influence the user; (iii) the modeling of the interactions with the user, following agent-based paradigms for autonomous behavior, and negotiation.

Throughout the paper, we use smoking cessation as a running example for the analysis of semantic modelling needs for behavior change systems.

2 Ontologies for behavior change models

Behavior change is a challenging problem, especially regarding health-related issues and lifestyle. There are different factors that need to be taken into account in order to achieve effective outcomes, including the attitude, emotional issues, social pressure, self-perception, etc. [1]. As each person has a particular background, context, and circumstances, even if the behavior change goals are similar, the strategies and techniques need to be personalized.

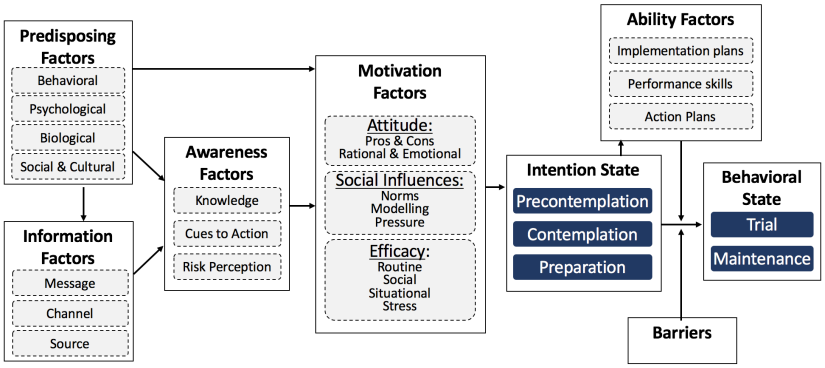

Fig. 1. I-Change model [3] for behavior change. Different states can be modeled, as well as the different types of factors that have an influence over the participant's behavior.

As it can be seen in classic behavior change models, participants may fall under different states, for which intervention may require complete different strategies and approaches. Although different such models exist (e.g. Trans-theoretical model of stages of change [2], Theory of planned behavior, I-Change model [3]), they share certain conceptual aspects. For instance the I-Change model (Figure1) incorporates different stages (similar to the trans-theoretical model), although it

adds elements, such as predisposing, information, motivation and ability factors, which have incidence on several aspects of the behavior change process.

As an example, for our smoking cessation use-case, participants may enter a contemplation state when they consider registering to the program, after realizing the benefits of quitting, while considering their own capacity to overcome addiction. Afterwards, once they enter the program, they may enter a preparation state in which they become aware of their consumption behavior thanks to the tracking of cigarettes through a chatbot. This step is crucial as they consciously learn about their own smoker profiles, which helps detecting which cigarettes are easily avoidable, what behaviors can be modified, and what effort is required to attain the desired cessation goals. Furthermore, during the cessation itself (trial/maintenance), the participants may be in different states depending on their chosen strategy: e.g., dealing with relapse and/or replacing smoking with alternative activities.

Using an ontology to represent these states within a behavior change model can help reusing concepts and relationships shared among them. For instance, the different intention states (e.g. precontemplation, contemplation, preparation) can be reused among different models, as well as their relationship with behavioral states. Moreover, information and awareness factors could feed from existing ontologies that already provide existing knowledge over a certain subject (e.g. ontologies for smoking cessation and prevention describing risks, facts, evidence, etc.). In sum, the modeling of behavior change models would require:

R1.1: *Stage modeling:* Generic states found in most models provide a high-level view over a participant's state with respect to a desired behavior change program/initiative. From these generic stages, more specific one can be derived depending on the use case.

R1.2: *Modeling of Factors & Barriers:* The different factors that my influence the change of state, as well as the development of a desired behavior change are numerous, and can be classified in different ways according to existing models. Motivation, awareness, and ability factors are common examples.

R1.3: *Composition:* The combination of different states and factors is desirable, considering that different models can establish alternative interactions patterns among them.

R1.4: *Triggers:* Moving form one stage to the other may happen in different manners, and often requires to be defined in terms of certain triggers, events or other type of signaling elements, which should be included in an ontological model.

3 Modeling plans & actions

Having defined a general behavior change model, the next step is to describe the plans and actions related to a certain stage of change. These plans refer to specific activities performed during a program or a treatment, which tend to be highly domain specific.

Ability factors in a behavior change model may include action plans, which can differ depending on the goals. As an example, in smoking cessation these action plans may include tracking cigarette consumption, preparing oneself for the cessation period (e.g., planning distracting actions), or reducing unnecessary cigarettes. Nevertheless, we can identify the following key elements:

R2.1: *Goals:* Participants of a health program may define different goals which may also depend on the stage they are in. For instance, on smoking cessation, the general goal is to quit smoking entirely. However, there may be intermediary phases, for instance during preparation or trail, for which the goal might be to reduce the cigarette consumption, or to at least identify those cigarettes that can be replaced by other activities. Goals may also be linked to constraints (e.g., duration) so that they can be evaluated.

R2.2: *Planning:* Following the goals, a set of activities can be defined according to a plan. For example, this may translate to monitoring context of consumed cigarettes (reporting mood, need level, circumstances, etc.), adoption of alternative activities replacing smoking (e.g., sports), or changing certain daily habits.

R2.3: *Feedback:* During a behavior change program, it is crucial to periodically assess the situation, in order to check if current measures are effective, or if amendments must be made to a plan. For instance, in case of relapse, it may be needed to understand the circumstances of failure. Or conversely, in case of positive results, how they can be maintained.

R2.4: *Personalization:* Plans and actions need to be adapted to the specific conditions and context of each participant, to maximize efficacy. People do not respond in the same way to a treatment or a program, for example in smoking cessation a participant may struggle more with social smoking, while others may have troubles dealing with stress. A participant behavioral profile should be modeled, in our case, through ontologies in order to capture these specificities and patterns.

4 Domain-specific vocabularies

As we mentioned before, domain-specific semantic models are important, in order to reflect accurately the different aspects relative to a health program. These ontologies may cover a number of different aspects, some of which we described throughout this paper. In this section we focus on those aspects that are generally not extensible to other domains.

Domain specific vocabulary requirements can be summarized as:

R5.1 *Profile data:* Data models must include domain specific information related to the user profile. This may include data intrinsic to the user (e.g. information of the participant history, behavior patterns, self assessment before, during and after the program, etc.)

R5.2 *Health issue data:* Ontologies may describe a pathology, a health issue/problem, including possible complications, relationship with co-morbidities, diagnosis, etc.

R5.3 *Treatments/Medication:* In some cases certain procedures, treatments and medications may be part of a behavior change program. In those cases, existing standards related to these information elements must be incorporated.

R5.4 *Messages and Communication data:* Information about a health problem, motivation and encouragement messages, among others, are fundamental in order to engage with participants, via different communication means (e.g. chatbot, facebook, email, etc.) In certain cases these materials are well known and can be reused or adapted to a degree.

5 Roadmap: Ontology-based behavior change applications

As we have seen, behavior change applications can benefit form existing theories, represented as behavior and intention states, influenced by different types of factors and barriers. Using ontology-based models as explained above, can provide a solid foundation for developing behavior change applications, considering not only the personal circumstances of a participant, but also the specificities of the health issue that is being addressed.

In summary, the success of these behavior change applications will require a combination of these models, and their reuse by agent systems that include them as part of their knowledge/beliefs/goals. The challenges and future work include:

(i) The design of **vocabularies and ontologies** for description, discovery and exchange within behavior change agents;
(ii) The development of specific **domain models** that can help enriching agent-based systems in areas such as physical rehabilitation, medication adherence, physical activity, sleep training, etc.;
(iii) Agent **coordination and negotiation** to incorporate computational persuasion into the agent execution logic;
(iv) The specification of **cooperation protocols** for participating agents, finding common problems and targeting community-based interventions;
(v) The **implementation** of the proposed model, and evaluation on a real environment with a considerable number of participants;
(vi) Ensuring **privacy protection**, using different approaches spanning from obfuscation to anonymity guarantees.

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