Personalized Message Emission in a Mobile Application for Supporting Therapeutic Adherence

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Abstract— **Often chronic patients fail to follow all the recommendations in their treatments. This affects their health and increases the costs associated with their care. To help these patients to follow their therapy this paper proposes a recall and guide system implemented on a mobile device. The system emits custom messages according to the patient's inferred mental state with the intention of persuading him to adhere to his medical prescriptions. To achieve personalization, the system uses ontologies to classify the messages and to model the user. When it is necessary to issue a reminder, the selection of the message is obtained by querying the relationships between the patient's current model and the discourse ontology.**

Keywords- Message Personalization, Mobile Application, Ontology User Model, Stages of Change, Therapeutic Adherence

I. INTRODUCTION

Adherence to treatment is the degree to which a patient adheres to medical recommendations [1]. For the past several years adherence levels have been low. It is estimated that almost 50% of chronic disease patients fail to follow their treatment to some extent. The negative impact of this behavior affects the patients' quality of life and many of them have to be hospitalized as a result. These unnecessary interventions represent a huge waste of money and resources for the medical service, together with a lower quality of life for patients [2]. Low adherence is a multifaceted problem with complex causes and relationships, including patient, environment and resource availability issues [3]. The patients' forgetfulness is one of the most influential factors in low adherence levels, especially when they have to follow a polimedication treatment and have to make changes to their habits [4]. Remembering a complex medication regime and integrating new activities in their lives often becomes an intense challenge for the patients. Many of them are old and have strong habits and beliefs deeply rooted in their minds.

Electronic devices have been widely used as an aid to help patients follow their treatments. Since the cell phone is so widespread, it has been identified as a potential ally for accomplishing this task. However, some difficulties arise when the cellphone is integrated as an aid in treatments. One facet of the problem is that fixed time reminders can emerge at bad moments, annoy the user, and reinforce his non-adherent behavior. Furthermore, given that the reminders may imply tedious, boring, clamant or unusual actions, the delivery of the reminder alone could be not enough. The user would receive the message, but he wouldn't be inclined to follow the recommendation. In the face of these problems, we propose an adaptive reminder system that emits personalized messages, created with the intention of helping patients diagnosed with cardiovascular disease to follow all their medical recommendations. Functions of the system are to issue opportune reminders with tailored and appropriate content that can persuade users to accomplish this goal.

Our system belongs to a more general project where many elements work in a coordinate manner in order to improve the adherence levels. Among the elements of the macro project are: a monitoring system using wireless sensors for capturing patient relevant variables, a smart pillbox that store medications and communicates its openings using Bluetooth messages, a remote call center system where medical staff receives alerts of low adherence and a server application for management of medical records. In this paper we are going to talk only about the mobile application and, particularly, about the strategy for the message personalization. More information about the macro project could be found in [5].

This article is structured as follows: Section II presents some useful concepts that help define the context of the discussion. Section III gives an overview of the proposed system. In Section IV we discuss in some detail the two main modules of the system: the domain and user models, showing how concepts from the semantic web were integrated. Section V explains how personalization is achieved using ontologies and Section VI presents the conclusions of the work.

II. THEORETICAL BACKGROUND

A. Treatment Adherence in Cardiovascular Disease Patients

The system is intended for patients diagnosed with a risk of cardiovascular disease. The treatment for these patients involves the following: taking medication, following diets, performing physical activities, attending medical appointments, adopting healthy habits and self monitoring the vital signs. The set of activities corresponding to each of these categories and their concrete temporal realization constitute the Care Plan. The medical staff asks the patient to follow the Care Plan, and it is commonly the patient's responsibility to find strategies for accomplishing this.

B. Cell phones used as a Supporting Tool in Cardiovascular Therapy

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Cellphones have achieved very high penetration. Nowadays most people carry one of these devices, which have evolved to integrate more and more services and have become more accessible to the general public. This puts mobile technology in a unique position to help people in different ways. In particular, people following complex treatments, or who need to change their behavior in some way, can find mobile applications very useful as an ally in the difficult task of creating new habits.

There is evidence that sending SMS messages to the patient has the potential to change some behaviors and achieve a more adherent attitude towards the treatment [6]. Furthermore, when these messages are personalized, the chances that users follow the recommendations are improved [7][8]. This article proposes a message delivery system in which the reminders are adapted according to the assumed mental state of the patient and the particular event requesting of interruption.

C. *Personalized Messages used as a Persuasion Strategy*

In the context of therapeutic adherence, aspects from the patient profile can be considered for message personalization, such as sex, age, socioeconomic status, illness, etc. However, and as a practical requirement of the system, the adaptation of the messages should be focused on ensuring that patients retain the behaviors that are successful for their therapy while modifying those that can be harmful. For this reason we decided that our system needs to be supported by a psychological theory of behavioral change. In this way the messages emitted have a role that is relevant to the treatment, and personalization is valuable in helping patients adhere to their therapy.

D. *Stage of Change Model*

The Stage of Change model (SoC), also known as the transtheoretical model, is an appropriate framework for identifying the patient's attitude to his treatment, and guiding him towards appropriate behaviors. It was proposed by Prochaska [9] several years ago and has been successfully used in multiple scenarios. In this model, patients progress through the mental states of pre-contemplation, contemplation, preparation, action, maintenance and termination, in order to assume a new behavior. A brief description of the states, relating to a bad habit in this case, is as follows:

1. *Pre Contemplation: People in this stage think they don't have any problem, that their behavior is acceptable, and they do not intend to change it soon.*
2. *Contemplation: Patients doubt that their behavior is acceptable, consider changing it, but don't have plans to do so in the short term.*
3. *Preparation: In this stage of change, people recognize that their behavior must change and they intend to do so soon.*
4. *Action: Patients actively follow a plan for changing their behavior.*
5. *Termination: The plan has been followed successfully for a long period of time.*

In each state there are clear guidelines regarding the type of messages that are appropriate to take the patient to the next stage in their behavior [10]. This model has been used by therapists for many years to help patients adopt healthy behaviors like quitting smoking, improving diet, taking medication, etc. [11] [12]. This model has also influenced the creation of some automatic systems for supporting medical treatments [13] [14] [15].

Our system is based on the Theory of Stage of Change, with the intention of selecting the message that is most appropriate to present, according to the current state of the patient and the type of reminder to be issued.

III. SYSTEM OVERVIEW

A general block diagram of the system is presented in Fig. 1.

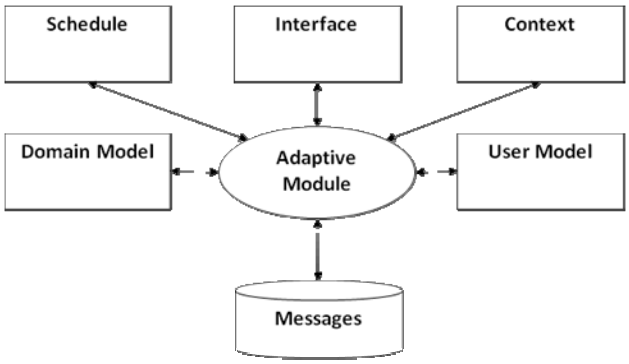

Figure 1. General block diagram of the system

Recall that the Care Plan given by the doctor to patients includes all the activities associated with the therapy (medication use, diet, exercise instructions, etc), linked to a specific schedule. The Schedule module is responsible for associating each item in the Care Plan with specific events in the mobile calendar. When one of these events needs to be issued, i.e. when the time for emitting a reminder is reached, the Schedule module informs the Adaptive module about it.

The Adaptive module evaluates the pertinence of generating an interruption at this time. This evaluation takes into consideration both the particular type of event and the patient's current context.

Our current implementation includes the following context variables: the interruption profile selected by the user (normal, silent, meeting) on the phone, the coincidence with a scheduled activity, and the current time. In our future work we aim to add more variables, such as the voice level in the environment, in order to avoid interrupting a conversation, and the spatial location of the patient.

Evaluation of the relevance of the interruption creates two scenarios. In one of them the system decides it is inappropriate to create a disruption at the current time. In this case, we evaluate the appropriateness of an automatic delay, considering how the context will change, when the task is due, and the priority of the type of reminder demanding attention. If it is decided that postponement is feasible, then the system

automatically updates the calendar event Otherwise the reminder is emitted, despite the timing being considered inappropriate.

If it is decided that the interruption is appropriate at the current time (or it cannot be postponed), then the Adaptive module queries the user and domain models, in order to select from the database the appropriate message, according to the type of reminder being issued. To understand how this selection takes place, we should describe in some detail how we model the user and the domain.

IV. Domain and User Models

Following lines similar to those given in [16], we use ontologies to model the domain and the user. The purpose of this modeling is to make a choice between a broad set of messages, to define which are the most appropriate to present to the user at a given time. We will begin by describing the architecture of the messages.

A. *Message Architecture*

The message that the user receives is composed of two main parts: a base message, indicating the reason for the interruption, and a guide message, selected according to the current state of the patient in the Stage of Change model. An example is shown in Fig. 2, which shows a reminder for taking a medication.

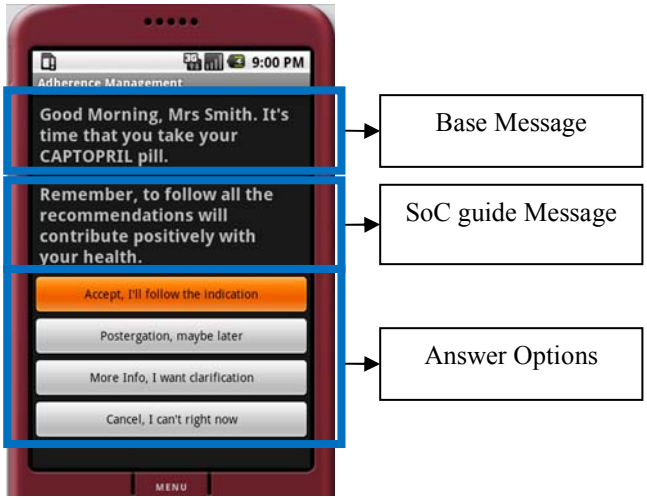

Figure 2. Example message showing a medication reminder

The base contains a greeting message to the patient and a specification that can be either a reminder to perform an action, a feedback to confirm that the user has followed a suggestion made previously, or an information message. For its part, the message guide is a phrase built on the model of Stage of Change, and selected under the assumption that the patient is in a particular stage in the model, with regard to the categories of the Care Plan.

In the following we discuss the specific ways in which messages are constructed with the help of ontologies.

B. *Domain Ontology*

The main objective of the domain ontology is to classify the messages the user will receive. It contains three main classes: BaseMsg, SoCMsg and Msg. The BaseMsg subclasses specify the construction of the base message, which include the greeting and a specific description relating to the reminder. The SoCMsg subclasses specify the different types of messages according to the theory of Stage of Change. Msg class references a complete message, and is constructed using the property hasPart, with a BaseMsg and a SOCMsg and according to the particular type of reminder. An excerpt of the ontology of messages is shown in Fig. 3.

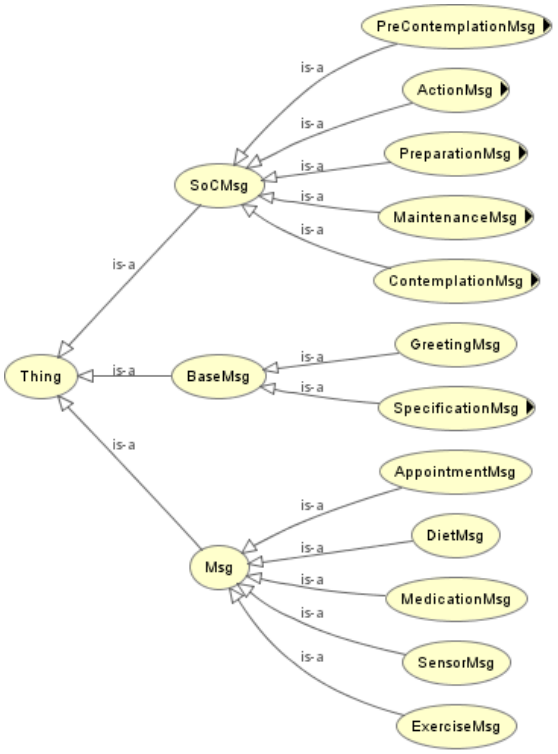

Figure 3. Excerpt from the Domain Ontology classes

All messages in the database are classified as belonging to one (or several) of the classes specified in the ontology. This allows us to select them in order to be deployed in the interface.

Once the reminder is emitted, the user has four options for responding to the message: accept, defer the reminder, request more information, or reject the indication.

Additionally, in relation with the SoC guide, the user has the option of reply to this message. When the patient interacts with the advice, three additional options emerge as possible responses. Two of these options represent transitions to the adjacent states in the SoC model, and the third is a reaffirmation that the actual state is in fact, a convenient assumption of the attitude of the user towards its treatment.

C. *User Modeling Using Ontologies*

The user model is also an ontology. We started from the general Gumo [17] model and we added the necessary elements to include the model of Stage of Changes. Under the

Gumo approach the user is modeled using a set of factors known as user dimensions. Each relevant dimension is described by three components: {auxiliary, predicate, range}. A subset of the user dimensions we used is shown in Table 1.

TABLE I. SUBSET OF THE USER DIMENSIONS THAT MODELS THE PATIENT

AUXILIARY	PREDICATE	RANGE
hasBelieve	StageOfChange	PreContemplation Contemplation Preparation Action Maintenance
hasProtocolarPref	Protocolar	Formal Neutral Informal
hasGroupAge	GroupAge	Young MiddleAge OldAge
hasInterruptionPref	InterruptionPref	RingTone Vibration
hasAdherenceLevel	AdherenceLevel	Low Medium High

The StageOfChange dimension models the assumed patient state in the transtheoretical model, for each category of activities in the Care Plan. The ProtocolarPref is a simple discourse categorization, intended to select phrases and words that best match the patient's speech style. The GroupAge is a helpful dimension that influences the protocolar style, and is assigned according to the age of the patient. For selecting the kind of interruption that every category of reminder is asssigned, we use the InterruptionPref dimension. And for storing the adherence level for each category of activities we employ the AdherenceLevel dimension.

Some dimensions, for a given patient, remain static for long time or do not vary at all, such as the name, age, etc. However, other dimensions may change as the patient progresses during treatment, such as level of adherence, reminder preferences, etc. For this reason we use two categories in the patient model: the static and dynamic views.

The static view involves the use of the userBasic individual. This individual is related to all static dimensions and, in general, is instantiated once, when the user model is created, and its specification remains unchanged. This individual is query to know, for example, the patient's name, age, type of disease, sex, etc. For example, if it is necessary to decide, for a particular message, between the referent "Mr" or "Mrs.", we seek the hasGender property of the userBasic individual.

The dynamic view brings together all the dimensions that will vary as the patient uses the system. For example, the preferences and the protocol may change over time. However, the main motivator for the dynamic view is the use of the theory of Stage of Changes. Recall that under this model the patient passes through a series of stages to adopt a new behavior. These stages depend, of course, on the particular behavior in discussion. Thus, for example, a patient could be in the Maintenance stage in relation to his medication intake, while, at the same time, he could be in the Contemplation stage in relation to the dietary category.

Given that our ontology contains generic classes related to the theory of stage of changes, i.e., without distinguishing the particular type of behavior, we decided to model this categorization on the individuals (another option would be to create specific classes for each behavior category, but this would extend the ontology and would add complexity). In particular, our individuals serve to model the different roles that the patient assumes in each category of behaviors. Our implementation uses six roles in order to categorize the patient's attitude to the six types of reminders in the Care Plan. The concrete individuals that represent these roles are: userRolMed, userRolDiet, userRolExcercise, userRolAppoint, userRolMonitor and userRolHabit, which model, respectively, the patients' attitude to their medication, diet, exercise, appointment attendance, self monitoring and healthy habits.

Each of these individuals has its own dynamic dimensions, and its evolution is, in principle, independent of the others. In this way we can model the typical case, where patients have different attitudes to different categories of behavior. This methodology can be broken down repeatedly. For example, in a diet all the different attitudes towards each facet of the diet can be considered. In this way, each particular behavior can be modeled independently and the system can customize the messages in more detail. We consider only the first stage, in which each category of the Care Plan is an individual which models the role of the patient to that category of behaviors. This view is schematized in Fig. 4, in which the individuals assume their roles according to the categories of the Care Plan.

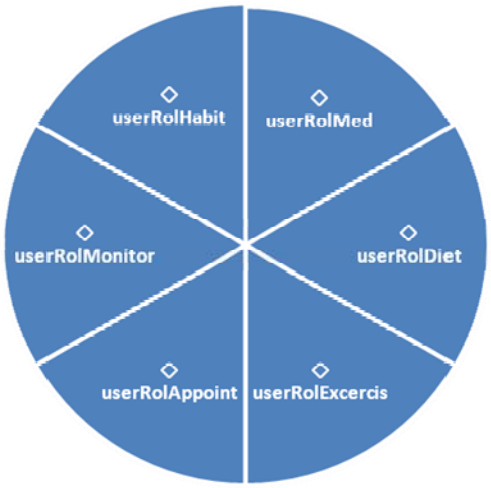

Figure 4. Set of individuals forming the dynamic view of the user model

When the user is first instantiated, the set of dimensions useful for personalization are allocated based on a questionnaire given by medical staff to each patient. Then the dynamic view of the user model evolves according to the changes in the user's treatment. As the patient interacts with the system, the dimensions that specify the user model assume different values, and we can deliver a more appropriate personalized message. The next section describes how these messages are selected using the ontologies.

V. Integration of Domain and User Ontologies for Selecting the Appropriate Message

A. *IsAdviceOf Relationship*

To select a message using the ontologies that describe the domain and the user, we created relationships that link the user dimensions with the message categories. In particular, to relate the StageOfChange dimension, we use the isAdviceOf relationship. For example, messages classified as appropriate for patients in the state of Pre-Contemplation are related to users who have the StageOfChange dimension in that state. The snippet in ACE [18] would be: Every PreContemplationMsg isAdviceOf a PrecontemplationUser.

Thus, when a message needs to be selected, the current user is classified according to his dimension values and, given his state in the Stage of Change model for each category, the system queries the most appropriate type of messages for the reminder to be issued.

B. *Patient Model Adaptation*

To determine the patient's progress in the Stage of Change model, the system has a limited set of inputs. These are outlined in Fig 5.

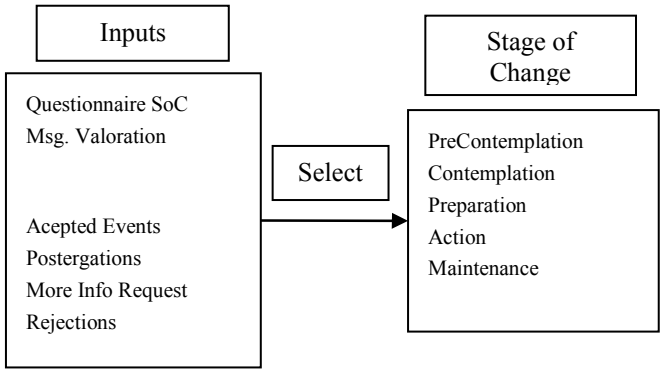

Figure 5. Inputs for adaptation and guessing the user attitude to his treatment

SoC questionnaires are short and low frequency tests. Their goal is to classify the user in relation to a particular activity involved in his treatment. For example, if we wanted to classify the patient in relation to his dietary habits, a possible questionnaire, taken from [7], is shown in Fig. 6.

In this questionnaire, two questions are enough to evaluate the patient's condition. Although very comprehensive tests could be created in order to achieve a more reliable classification, our intention is not to tire the user with a large number of questions. Moreover, given that the platform application deployment is a mobile phone, it could be very cumbersome to fill out a long questionnaire, and this could affect the usability of the software.

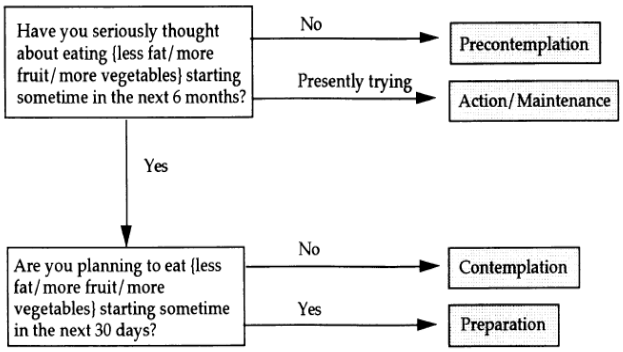

Figure 6. Questionnaire for classifying the user according to his attitude towards dietary habits

The concrete responses from the user to each reminder also provide valuable information for guessing the stage of the patient for each role. For example, a user that is believed to have a high state of follow-up in his treatment, such as Maintenance in the medication role, and whose responses indicate that he is not taking his medication, could warn the system about a possible relapse recession or an error in the current believed state. We think the history of interactions offers a correlation between the real state of the patient and the assumption that the user model makes.

Another input to the system that we plan to investigate is the rating given by the user to the messages. This optional tool allows us to judge indirectly the relevance of the current user state, considering how effective the message was, and how appropriate the user finds the guidance the system gave to him, according to his current condition.

VI. Current Implementation

We completed the implementation of a proof of concept on a desktop computer using the Jena framework. Our current efforts are focused on porting the code into a mobile application. We are using the Androjena framework in order to utilize all the semantic web tools required to materialize the system described on a mobile device.

Our goal is to do all the querying and reasoning necessary on the phone, without the need for a server connection every time the system needs to emit a message.

VII. Conclusions

We have presented a design for a mobile application that uses semantic web concepts, in order to create a personalized message delivery system that helps patients adhere to their therapy.

Our work defends the hypothesis that a system in which each message is deployed at the right moment and is created according to the rules of psychological persuasion will support

the treatment of chronic patients and will contribute to the adoption of healthy habits.

Future evaluations of the system will provide further answers concerning this topic and, if positive results emerge, we will be happy to have contributed to helping chronic patients.

REFERENCES

[1] R.B. Haynes and D.L. Sackett, *Compliance with therapeutic regimens*, Johns Hopkins University Press, 1976.

[2] G.E. Silva, E. Galeano, and J.O. Correa, "Adherencia al tratamiento implicaciones de la no-adherencia," *Acta Med Colomb*, vol. 30, 2005.

[3] E. Sabate and others, "Adherencia a los tratamientos a largo plazo: pruebas para la acción," *Organización Mundial de la Salud (OMS)*, 2004.

[4] S.C. Kalichman, D. Cain, C. Cherry, M. Kalichman, and H. Pope, "Pillboxes and antiretroviral adherence: prevalence of use, perceived benefits, and implications for electronic medication monitoring devices," *AIDS Patient Care & STDs*, vol. 19, 2005, p. 833–839.

[5] F. Duitama, N. Gaviria Gómez, and J.E. Aedo Cobo, *Reporte Técnico Macroproyecto Telesalud (ARTICA)*, Universidad de Antioquia, 2008.

[6] H. Cole-Lewis and T. Kershaw, "Text messaging as a tool for behavior change in disease prevention and management," *Epidemiologic reviews*, 2010.

[7] M.K. Campbell, B.M. DeVellis, V.J. Strecher, A.S. Ammerman, R.F. DeVellis, and R.S. Sandler, "Improving dietary behavior: the effectiveness of tailored messages in primary care settings.," *American Journal of Public Health*, vol. 84, 1994, p. 783.

[8] W. Kroeze, A. Werkman, and J. Brug, "A systematic review of randomized trials on the effectiveness of computer-tailored education on physical activity and dietary behaviors," *Annals of Behavioral Medicine*, vol. 31, Jun. 2006, pp. 205-223.

[9] J.O. Prochaska, W.F. Velicer, J.S. Rossi, M.G. Goldstein, B.H. Marcus, W. Rakowski, C. Fiore, L.L. Harlow, C.A. Redding, and D. Rosenbloom, "Stages of Change and Decisional Balance for 12 Problem Behaviors," *Health Psychology*, vol. 13, 1994, pp. 39-46.

[10] M.A. Rapoff, *Adherence to pediatric medical regimens*, Springer Verlag, 2009.

[11] G. McKee, J. Bannon, M. Kerins, and G. FitzGerald, "Changes in diet, exercise and stress behaviours using the stages of change model in cardiac rehabilitation patients," *European Journal of Cardiovascular Nursing*, vol. 6, 2007, p. 233–240.

[12] K.S. Astroth, A.F. Fish, G.L. Mitchell, J.A. Bachman, and K.H. Hsueh, "Construct validity of four exercise stage of change measures in adults," *Research in Nursing & Health*, vol. 33, 2010, p. 254–264.

[13] T.W. Bickmore and C.L. Sidner, "Towards plan-based health behavior change counseling systems," *Argumentation for Consumers of Healthcare, AAAI Spring Symposium Series*, 2006.

[14] F. Rosis, N. Novielli, V. Carofiglio, A. Cavalluzzi, and B.D. Carolis, "User modeling and adaptation in health promotion dialogs with an animated character," *Journal of Biomedical Informatics*, vol. 39, 2006, pp. 514-531.

[15] A. Cavalluzzi, V. Carofiglio, and F. De Rosis, "Affective Advice Giving Dialogs," *Affective Dialogue Systems*, 2004, pp. 77-88.

[16] E. Erriquez and F. Grasso, "Generation of Personalised Advisory Messages: An Ontology Based Approach," *Computer-Based Medical Systems, 2008. CBMS'08. 21st IEEE International Symposium on*, IEEE, 2008, pp. 437-442.

[17] D. Heckmann, T. Schwartz, B. Brandherm, M. Schmitz, and M. von Wilamowitz-Moellendorff, "Gumo–the general user model ontology," *User Modeling 2005*, 2005, pp. 428-432.

[18] T. Kuhn, "Controlled English for Knowledge Representation," 2009.