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Human-Agent Dialogues on Health Topics - An Evaluation Study

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Abstract. A common conversation between an older adult and a nurse about health-related issues includes topics such as troubles with sleep, reasons for walking around nighttime, pain conditions, etc. This dialogue emerges from the participating human's lines of thinking, their roles, needs and motives, while switching between topics as the dialogue unfolds. This paper presents a dialogue system that enables a human to engage in a dialogue with a software agent to reason about health-related issues in a home environment. The purpose of this work is to conduct a pilot evaluation study of a prototype system for human-agent dialogues, which is built upon a set of semantic models and integrated in a web application designed for older adults. Focus of the study was to receive qualitative results regarding purpose and content of the agent-based dialogue system, and to evaluate a method for the agent to evaluate its behavior based on the human agent's perception of appropriateness of moves. The participants include five therapists and 11 older adults. The results show users' feedback on the purpose of dialogues and the appropriateness of dialogues presented to them during the interaction with the software agent.

Keywords: Human-agent interaction, Human-agent dialogue, Health, Active assistive technology, Evaluation, User experience

1 Introduction

Assistive technology aims to support an individual in accomplishing activities, which they need to be able to do in the presence of decreased functionality or ability. In this work the definition of *active* assistive technology, used by Kennedy and co-workers [1], is applied to distinguish systems, which includes automated processing of health information during a human agent's interaction with the system and which may output tailored responses to the human agent in the process. The purposes of active assistive technology include the following: to increase knowledge, assist in deciding about actions to make, and promote changes of unhealthy behavior (i.e., in the form of *behavior change systems*).

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Our work focuses on dialogues between a human actor and an active assistive technology in the form of an intelligent software agent. The concept of Embodied Cognitive Agents (ECA) is generally used for such systems. The ECA uses a virtual representation of a human with the ability to send information through body language in addition to linguistic messages. However, we restrict the focus in this work to structured linguistic dialogues based on semantic models of relevant knowledge.

In this article, a dialogue system is presented, which enables a human actor to conduct a dialogue with a software agent for the purpose of handling health-related issues in a home environment. The aim is to enable the dialogues between a human agent and a software agent, which are tailored to the human's needs, preferences and goals. The goal is to build a software agent that interacts with the human as their personal coach, friend or a discussion partner, i.e., as a *Coach Agent* as described in [2]. A prototype dialogue system was implemented and integrated in a web-based support application designed for older adults, which enables the human actor to conduct a dialogue with the Coach Agent in their home environment. The prototype was evaluated in a pilot study involving a group of older adults and a group of therapists.

This paper is organized as follows. In the following section the methods are described and in Section 3, a brief description of the human-agent dialogue system is provided. The results of the pilot evaluation study is presented in Section 4. In Section 5, the results are discussed in the perspective of related active assistive technologies described in literature. The article ends with conclusions and comments on future work.

2 Methods

A pilot evaluation study was conducted involving a group of five female professionals in occupational therapy and physiotherapy, specialized in the needs of older adults, and a group of eleven older adults, six women and five men. The study was formative, with the results aimed to inform further development. The main research questions, which were targeted by the evaluation study, were related to the overall idea of a dialogue system for supporting everyday issues, how a sense-making dialogue would unfold and what topics would be interesting to elaborate upon. Other research questions were related to interaction design of the dialogue system.

The evaluation study was limited to the initiation of inquiry dialogues and the conduction of nested information-seeking dialogues [3], in the context of a use case scenario of an older adult called Ruth [2]. The information about Ruth forms the base for the Coach Agent's user model and the priorities of goals and tasks. An example is given in Figure 1. This information and consequently, the user model changed during the testing, depending on how the participants interacted with the system.

Observation of use and interviews were the methods used for collecting the data.

User model	
CaseID	1371670200235
Firstname	Rut
Gender	female
Sleep	Very important
Well-being	Most important *
Medication	Very important
Family and friends	Most important
Exercise	Very important
Keep up with society	Important
* indicates highest importance	
Activities to support	
1. Sleep routines	
2. Do funny things	
3. Find and balance the amount of activities	
4. Contacts with family and friends	
5. Keep track of economy, birthdays, etc.	
6. Exercise for strength and balance	
7. Get started doing things	
8. Keep track of the health and well-being	
9. Food routines	
10. Contacts with healthcare and authorities	
11. Medication routines	

Fig. 1. Screenshot of a user model generated by the Coach Agent based on the preferences and needs of the individual.

During the study, the older adults and two of the therapists were individually given the tasks to play the role of either the persona in our scenario, some other person or themselves. The participants could also play both the roles one after the other. After deciding the role they play, they were asked to select topics of interest to initiate a dialogue and respond the way they wished. The user was also asked to evaluate the appropriateness of each statement of the Coach Agent within its context where it was stated by marking one of four alternatives on a Likert scale, presented in connection to each of the Coach Agent's statements. A purpose of the pilot study was also to evaluate this method. The system and the scenario were demonstrated to the remaining three therapists in a focus group session and discussed. The data was analyzed qualitatively using content analysis.

3 The Human-Agent Dialogue System

The human-agent dialogue system is developed as a part of the architecture of the agent-based ambient assistive living system presented in [2]. The architecture integrates knowledge repositories, developed using ACKTUS (Activity-Centered modeling of Knowledge and interaction Tailored to USers)[4, 5]. ACKTUS is a platform for end-user development of knowledge-based systems in the medical

and health domain. These repositories are built on semantic models represented using RDF/OWL¹, which were in [6] extended to integrate components vital for enabling the agent dialogues, based on the canonical model for agent architectures presented by Fox and coworkers [7].

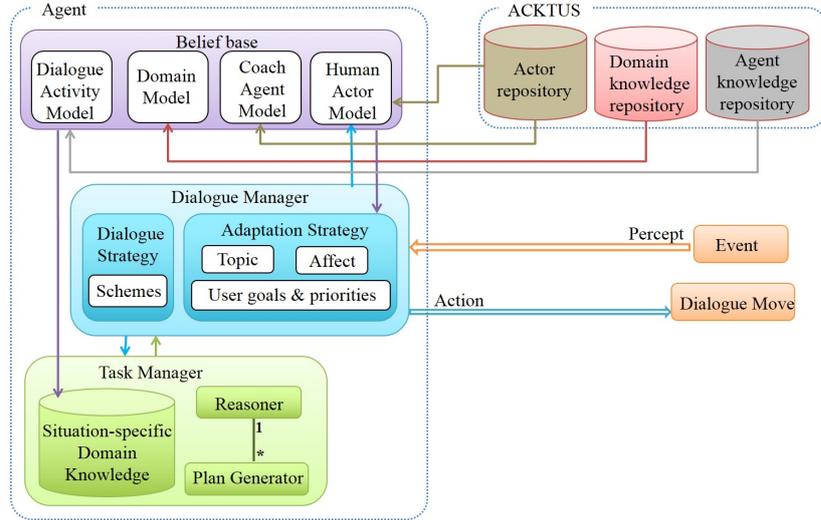


Fig. 2. Architecture of the human-agent dialogue system.

The software agent comprises of a belief base, a dialogue manager and a task manager (Figure 2). The agent builds its belief base upon information retrieved from the relevant ACKTUS repositories depending on the topic and who the user is. The human actor and the software agent interact with each other via events and dialogue moves, which are displayed in the graphical user interface (Figures 2, 3).

The ACKTUS knowledge repositories were created by domain experts in the rehabilitation domain [5] among other. The knowledge consists of both factual knowledge related to a user, which is used for creating a baseline user model, and procedural knowledge, in the form of rules obtained from domain knowledge repositories. Moreover, interactive templates, or protocols for assessment of different aspects can be retrieved from the domain knowledge repositories, which formed the basis of an earlier dialogue system presented in [8]. The knowledge was structured and implemented by the domain experts, to be used as assessment protocols by therapists in clinical interviews, or in human-agent dialogues. As a consequence, the topics and associated knowledge are structured, in that there is typically a set of answer-alternatives defined by the domain expert associated to each question in the knowledge base (e.g. Figure 3). Each constructed piece

¹ <http://www.w3.org/>

of information is also associated to a concept, which is organized in an ontology, and which provides the theme of a topic to the software agent.

A generic model of purposeful human-agent dialogues about health-related topics builds the base for the human-agent dialogue system. The model was based on analyses of scenarios, personas and models of human behavior. The resulting conceptual model includes four models, which are included in the software agent's belief base; i) a user model, ii) a model of the domain knowledge related to the topic of the dialogue, iii) an agent model, and iv) a dialogue activity model [9]. The architecture for a human-agent dialogue system presented in [10] was extended with the agent and dialogue activity models and is partially implemented. The system is integrated in a web-based support application designed for older adults, which is also used for therapist-lead assessments through structured interview-protocols (Figure 3).

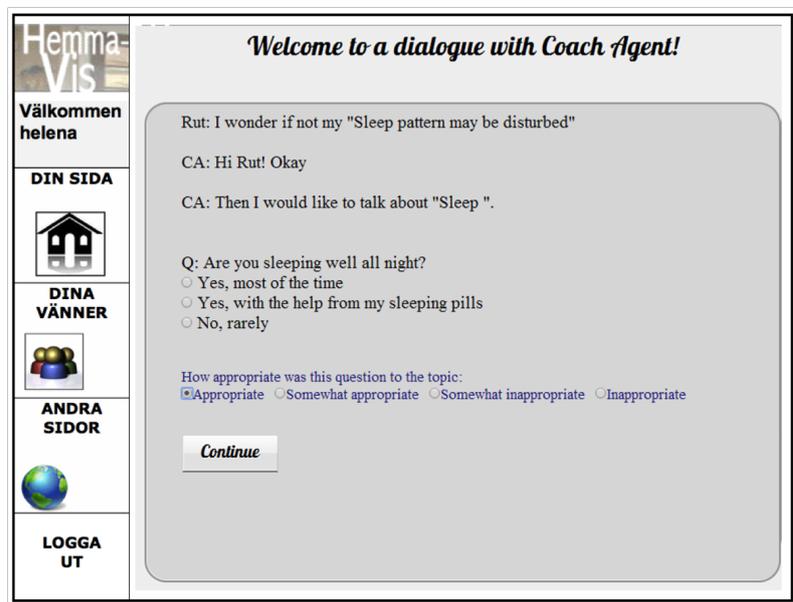


Fig. 3. Screenshot from the human-agent dialogue system. The agent collects the perceived appropriateness/ inappropriateness of each of its question posed during the dialogue.

4 Results

The main research questions addressed in the evaluation study is related to the overall idea of a dialogue system for supporting everyday issues, how a sense-making dialogue would unfold and what topics would be interesting to elaborate

upon. Other research questions are related to interaction design of the dialogue system. Since the evaluation study was limited to a subset of the models described in this article, and the study sample was small, the results are only indicative, aimed to inform further development.

A purpose was also to evaluate the method to allow the user to evaluate the appropriateness of each of the Coach Agent’s statements within its context where it was stated. A question about the appropriateness of the agent’s behavior was associated to a four-item Likert scale with the values *inappropriate (1)*, *somewhat inappropriate (2)*, *somewhat appropriate (3)* and *appropriate (4)*. The 13 participants’ interaction with the dialogue application was logged, and resulted in a corpus with a total of 28 dialogues, 156 complete turns, and a total elapsed time of 2 hours (approximately 10 minutes per participant). The examples from the dialogues presented in this section have been translated from the participants’ native language into English. The results are divided into results related to the interaction design, the purposes of dialogues, and the appropriateness of the agent’s behavior in the following sections.

4.1 Interaction Design

The older adults did not comment on the visualization of dialogues in the graphical interface. By contrast, the therapists put significantly more interest in how the dialogues would appear to the user. They commented on what parts of the dialogue line were visible at different phases in the dialogue, the unfolding of dialogues, on how the responses would be given by the user, etc. Their main concern was, how to reduce the amount of information presented to the user, while not losing the information about in which context the dialogue was situated. The interface design will be improved based on their comments and suggestions.

One therapist mentioned the concept of an "avatar", sometimes used for representing an Embodied Cognitive Agent (ECA). She viewed the Coach Agent as such, and discussed how body language could be added to the static figure used in the graphical user interface for representing the Coach Agent. Other comments related to the benefits of, and how to mediate, the dialogues through spoken language instead of text. Testing voice-based dialogues will be a natural step towards a more adaptive human-agent dialogue system, considering the large proportion of older adults who have sight impairments. One obvious benefit from using the ontology-based semantics of dialogues, was illustrated in the pilot evaluation study, since it allowed to apply the two languages needed by the participants. This will also facilitate the inclusion of additional modalities in the interaction design, which will be evaluated in future studies.

4.2 Purposes of Dialogues

The dialogues were based on the fictive persona Ruth’s health and priorities. Most of the participants could personally relate to the dialogue topics, a few referred to a family member. In general, the available dialogue topics were considered interesting and relevant.

A generic attitude among the participants was that there is need for supportive dialogue systems, on various themes. Additional health-related topics, which were suggested were topics related to eating habits and eating disorders. Besides having healthcare issues to discuss, some pointed out the need in particular situations, when getting lost in the forest, or misplaced a car in the forest or bike in the city center. Others pointed out the potential benefits relating to getting access to social networks, having dialogues about societal issues such as politics, weather, golf and other sports.

A few expressed enthusiasm and curiosity about the idea and wanted to use the dialogue system merely for the fun of it: "...this is fun, let me try another one!"

Two of the older adults expressed skepticism, and did not see the point in using the dialogue system. One of these had also some difficulties using a smart phone, which may indicate a threshold for using new technology in general. By contrast, the other skeptical older adult was already using alternative ways to accomplish potential dialogue purposes, by using search engines for health issues, GPS for navigating, etc. Consequently, the group of participating older adults, including the two skeptical persons, illustrates the broad heterogeneity of the group of older adults.

The therapists highlighted the potential benefits of using a proactive human-agent dialogue system for providing active support for improving strength and balance, e.g., by supplementing the dialogues with sensor information from daily activities and physical exercises performed, analyzed over time.

4.3 Perceived Appropriateness of the Agent's Moves

One of the therapists who tested the system perceived the approach to evaluate the moves within the context it occurs, as highly beneficial. She compared it to structured clinical interviews, where it is typically not known how the patient perceives the appropriateness of the question asked.

The question, which was used for evaluating the appropriateness of the agent's moves, was found to be used in two different ways. Based on this observation, we distinguish between two types:

1. *Context-related appropriateness*: the appropriateness based on the immediate context of the agent's move, e.g., placement in the dialogue line, and
2. *Topic-related appropriateness*: appropriateness related to the topic of the dialogue.

The moves, which were categorized as the first kind and valued inappropriate to some level, were considered a failure of the agent, and are aimed to be minimized by improved strategies for the agent to use when choosing behavior. Consequently, these were removed, when analyzing the second kind, which was considered relating to the domain knowledge and not behavior issues.

Table 1. Total number of dialogue turns (Turns), number of Contextual Appropriateness Errors (CAE: turns, which are to some extent inappropriate), and mean of errors

User	1	2	3	4	5	6	7	8	9	10	11	12	13	Total	Mean
Turns	13	13	8	9	13	28	28	9	9	9	8	9	11	167	12.8
CAE	1	1	1	4	1	0	3	2	0	1	1	1	0	16	1.2

Context-related appropriateness: Regarding the context-related appropriateness, some of the agent’s moves were considered as inappropriate to some extent due to the agent’s inadequate understanding of the human’s responses. The agent needs to understand the context of human’s response, update its belief base and act accordingly. Therefore the agent needs strategies for wisely selecting moves based on the human’s response and the unfolding of the dialogue line.

For evaluating the agent’s improvement of behavior for future studies, a Contextual Appropriateness Value was defined and tested on this data sample. The total contextual appropriateness value for the complete corpus was 90.4%, and consequently, the error rate was 9.6% (16 of 167 moves) (Table 1).

Table 2. Perceived topic-related appropriateness: inappropriate (✗), somewhat inappropriate (✗), somewhat appropriate (✓) and appropriate (✓) . The abbreviation (*n/a*) (not available) represents missing information where a particular question was not asked to the user or the user chose not to give feedback.

Ques	Users												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Sleeping well all night	✓	✓	✓	<i>n/a</i>	✓	✓	✓	✓	✓	✗	✓	<i>n/a</i>	✓
Cause of getting up at night	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	<i>n/a</i>	✓	✓
Severity of pain	✓	✓	✓	<i>n/a</i>	✓	✓	✓	✓	✓	<i>n/a</i>	<i>n/a</i>	✓	✓
Having worries	✗	<i>n/a</i>	<i>n/a</i>	✓	<i>n/a</i>	✓	✓	✓	✓	<i>n/a</i>	<i>n/a</i>	✓	✓
Severity of worries	✓	✗	<i>n/a</i>	✓	✓	✓	✓	<i>n/a</i>	✓	✗	✗	<i>n/a</i>	✓
Taking some medication	✓	<i>n/a</i>	✓	<i>n/a</i>	✓	✓	<i>n/a</i>	<i>n/a</i>	✓	✓	<i>n/a</i>	<i>n/a</i>	✓
Handling medications	<i>n/a</i>	<i>n/a</i>	✗	✓	<i>n/a</i>	✓	✓	✓	✓	<i>n/a</i>	<i>n/a</i>	✓	✓

Topic-related appropriateness: To what extent the agent’s moves were perceived by the participants to be relevant to the overall dialogue topic was analyzed. The agent uses the domain knowledge, which it retrieves from a domain knowledge repository modeled by domain experts, to build a model of the knowledge domain, related to the selected topic of a dialogue. The domain experts have in their modeling created a knowledge model with interrelated topics following their view on to what extent different phenomenon are relevant to each other. However, human individuals who have a dialogue with the agent may perceive the

level of appropriateness differently. We evaluated this topic-related appropriateness based on the participants' answers to the question about appropriateness, and mapped them to the concept associated to the content of the agent's move.

The most common topic, which the participants selected was the topic *sleep patterns may be disturbed*. The corresponding concept is *sleep*. Table 2 provides a summary of the participants' responses about appropriateness of different moves in relation to sleep. After removing the contextual errors and missing information (marked as not available (*n/a*) in Table 2), we can observe that most of the turns made by the agent were considered as appropriate to the topic sleep.

5 Discussion and Related Work

A software agent may have the capability to adapt to user's pace of communication and interacts in a nonjudgmental manner as described in [10–13]. Research literature shows an increasing number of applications of software agents that interact with the human actors for health-related purposes (e.g., [14–18, 11]). A review of behavior change systems utilizing personalization technologies for accomplishing active assistance is provided in [1]. It was concluded that an agent provides an effective interface modality especially for the applications that require repeated interactions over longer period of time, which is crucial for applications supporting behavior change [1, 12]. One example is the system, which has been developed for older adults with cognitive impairment described in [14]. However, it focuses mainly on generating reminders about the activities of their daily living and takes no part in a complex dialogue with the user. Agent-based systems which interact with human actors through dialogues are less common. They are typically developed for a specific task or for a limited domain, and the dialogues are tested in specialized environments [11, 17].

Bickmore et. al [11] developed an animated conversational agent that provides information about a patient's hospital discharge plan in an empathic fashion. The patients rated the agent very high on measures of satisfaction and ease of use, and also as being the most preferred over their doctors or nurses in the hospital when receiving their discharge information. One of the reasons for the positive results in this study was the amount of time that the agent spent with users helped them to establish a stronger emotional bond. Our approach has the same potential, in that there is no time limit, and the dialogues can reoccur whenever the older adult may wish to have a dialogue. The prototypic graphical user interface used in our study was commented upon by the therapists, who suggested that an animated agent would be an interesting improvement, as well as using spoken language. A difference in evaluation methodology is that their analysis was carried out after the dialogue had been completed with a summative purpose, using questionnaires with no particular focus on the software agent's interactive behavior in dialogue situations. Our method aims at tuning the behavior to the human agent's experience, which was also received positively by the therapists in our study.

The counseling dialogue system discussed in [12] also uses an ontology to represent the user model and the domain knowledge. The domain knowledge is based on behavioral medicine. However, the domain experts are not directly involved in the modeling of the agent's knowledge in this system. As a consequence, it lacks features for modifications, such as future changes in domain knowledge and also it lacks the representation of goals, which drives the behavior of the dialogue system.

Different approaches to developing and implementing behavior change systems in healthcare for older adults have been documented in the literature [19, 1, 20, 18, 11], but to our knowledge, there has been no attempt to design a method for a software agent to analyze its own behavior for improving its behavior when interacting with the older adult. For instance, [16] tested their dialogue system by letting the users use the system for 2 months and at the end of 2 months, an experimenter conducts a follow-up meeting. During the meeting, they used questionnaires to evaluate various aspects of intervention. However, this study lacks in exploring the behavioral aspects especially focusing on the agent, which they point out to be very important. The same authors in another work [15], evaluate a conversational agent based on behavioral measures such as rate of speech and type of utterance but not the relevance of the utterance to that of the previous utterance or the overall dialogue topic. Hence, we evaluated our agent based on the appropriateness of the agent's move as a behavioral measure.

Identifying the topic-related appropriateness of a participant's moves is to a large extent dependent on the perspective of an individual. Some participants considered the questions related to pain and the presence of worries as appropriate while some others considered the same topics as inappropriate to different extent. Some comments by the participants indicated that they associated these questions to their own situation and health conditions, rather than the persona Ruth's situation, which was the reason for why these moves were perceived as inadequate. Consequently, if the participants had been able to create their own profile in the system for the agent to build a user model from in the dialogues, then some of these less appropriateness evaluations had been different. The question about reasons for why getting up at night had a broad range of answering alternatives, among which a few participants found less relevant alternatives.

The overall goal of our human-agent dialogue system is to minimize the contextual appropriateness errors and maximize the topic-related appropriateness. To attain this goal, future work includes developing strategies for the agent to wisely select moves based on changes in its belief base. Moreover, these improvements will be evaluated with a group of older adults who create their own profiles in the system, for evaluating to what extent the perceived inappropriateness is related to the domain knowledge, and the differences in the view on this. If the differences are significant, a machine learning method will be built for the agent to learn how an individual values the topic-related appropriateness and adapt its selection of moves to that individual.

To summarize the results regarding the described method of valuing the appropriateness of the agent's behavior within its context where it occurs, the

approach was found to add significant value to the evaluation study, without disturbing the participant from participating in the dialogue. The advantage of this method is that a software agent can learn 1) what an individual user thinks is appropriate, also 2) learn based on a number of people with different characteristics, how some topics are perceived more or less appropriate, depending on the context (human's age, gender, type and/or severity of disease, current main topic, etc). However, considering the limitations of the pilot study, in particular the quantified analyses in relation to the limited number of participants, and the two possible ways to interpret the question, the method will also be further developed and evaluated in future studies.

6 Conclusions

In this paper, a dialogue system that enables a human to engage in a dialogue with a software agent to reason about health-related issues in a home environment was presented. The main contributions of this paper are the insights about the perception of this human-agent dialogue system by older adults and therapists. A new method for an agent to evaluate the appropriateness of each of its move was also presented. Finally, an evaluation of the initial prototype system was presented, which was evaluated by therapists and a group of older adults. The study shows results related to users' feedback on the purpose of dialogues and the appropriateness of dialogues presented to them, during the interaction with the software agent. Future work involves evaluation of the proposed method with different topics such that it can be generic for selecting appropriate behavior, to test the agent's capability of selecting what is perceived appropriate to talk about in different contexts. Future work also includes the development of the dialogue and reasoning strategies for the agent to improve its ability to adapt to the individual and the situatedness of contextual and natural dialogues.

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