Co-Designing Ambient-Assisted Interventions using Digital Interlocutors for People with Dementia

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Abstract
Socially assistive robots (SAR) have been used to assist the care of persons with dementia (PwD). We propose to combine problematic behaviors detection and robot interventions in an Ambient-assisted Intervention System (AaIS). To achieve this long-term aim, our first step was to design and evaluate robot-based interventions. We describe the co-design process conducted with caregivers to define realistic application scenarios for a conversational robot, named Eva, to enact interventions. Most recommendations from the caregivers in the co-design session were implemented in Eva. We conducted two sessions of a music therapy intervention with the new version of Eva with six PwD at a geriatric residence. Preliminary results from the intervention showed that the residents enjoyed the sessions, they talked to Eva to request songs, answered questions made by the robot and sang with it.

Author Keywords
Conversational Robot; Persons with Dementia; Ambient-assisted Intervention System; Problematic Behaviors

ACM Classification Keywords
H.5.2. User interfaces, J.3. Computers applications (Health)

Introduction

Dementia is a syndrome that can be caused by a number of progressive illnesses that affect memory, thinking, behavior and the ability to perform everyday activities which cause disability and dependence.

People with dementia often experience behavioral and psychological symptoms of dementia (BPSD). These are symptoms of disturbed perception, thought content, mood, and behavior [3]. Non-pharmacological interventions (NPI) aim at reducing the incidences of BPSD and stimulating changes in behavioral patterns in PwD and their caregivers [15].

An Ambient-assisted Intervention System (AaIS) leverages on pervasive technologies to detect BPSD in PwD to enact interventions in an overly-disruptive environment, suggest interventions to the caregiver, or prompt the PwD to carry out comforting activities [10]. These problematic behaviors can be observed and reported by the caregiver or can be inferred from information obtained from sensors in the environment or worn by the PwD to detect when an intervention is appropriate.

Social Assistive Robot (SAR) systems have been used to support interventions based on companionship and social interaction, physical and mental activity. A SAR is a system that employs hands-off interaction strategies, such as the use of speech, facial expressions, and communicative gestures, to provide assistance in accordance to a particular healthcare context [11].

Our final objective is to combine problematic behaviors detection and robot interventions in an AaIS. As an initial step, we are focusing on designing robot interventions and assessing their adoption by PwD. Hence, we describe the co-design of a conversational robot to interact with PwD, and present preliminary results of an intervention with six PwD using the robot.

Related Work

SAR is primarily concerned with robots that provide assistance through social, rather than physical, interaction [8]. The childlike robot Bandit II was used in [7] as an exercise instructor. A feasibility study found that the robot could motivate participants to perform simple physical exercises. The robot Brian 2.1 [9] can engage elders in both self-maintenance and cognitively stimulating leisure activities. The robot enacts appropriate assistive behaviors based on the state of the activity and a person's user state. Robovie [14] is a conversational robot designed to engage in daily greetings and chatting with elders. A study in an elderly care center showed that Robovie was accepted by the residents.

Music therapy interventions with robots have been reported in other mental care scopes. A robot was designed to instruct children with autism to imitate dance movements through a therapist-selected song [2]. Results showed that the children increased imitation over the course of the study. Combining musical therapy and social robots, children with autism exhibited more playful and prosocial behaviors during the therapy sessions [17].

Eva: a conversational agent

Digital interlocutors (e.g. artificial conversation entities, artificially intelligent software agents, robots) are emerging in all aspects of everyday life. The popularity of devices like the Amazon Echo provides new opportunities to study how people perceive and respond to such conversational agents [13].

Figure 1: The robot Eva.

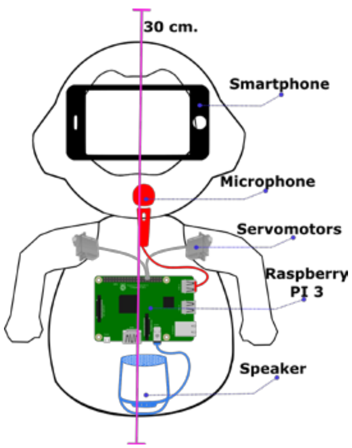

Figure 2: Eva's hardware components.

In our AaIS, the digital interlocutor is used to enact an interaction to distract persons who suffer from dementia and lessen caregiver burden. In a previous study [4], we found that the main social interaction strategy to deal with problematic behaviors, is to enact a personalized conversation with the residents. Caregivers often use this strategy to calm, distract, and relax PwD. Thus, we envision a digital interlocutor that can enact conversations and activities customized to the personality and preferences of each PwD.

Our digital interlocutor is a conversational robot. We have developed a conversational robot prototype, named Eva (see Figure 1), who has autonomous features such as natural language understanding, emotion enactment, and talking. Eva's architecture is embedded in a Raspberry PI board, and employ sensors (microphone) and actuators (speaker, servomotors) connected to the board, and a smartphone to display Eva's eyes (see Figure 2). Furthermore, a human operator can interrupt or trigger a specific behavior of Eva via a Web application. We propose this semi-autonomous approach to conduct formative evaluations with potential users and to elicit requirements and potential scenarios for an AaIS. All interactions with the robot Eva are stored in a module, which resides in a FIWARE cloud to build a log of each interaction.

We implemented intervention tasks in the robot Eva based on findings from a previous study [4] and a review of the literature. The Alzheimer's Association has published guidelines for activities aimed at stimulating PwD [1]. Many of these activities are based on verbal communication. These activities include: inviting the person to tell you more when he or she talks about a recent memory; telling jokes; completing famous sayings; asking the person about her favorite hobby or her family. Thus, the autonomous activities supported by Eva include telling time and date, triggering smalltalk (greetings, tell/ask name), telling jokes, and playing word games, such as completing sayings. Furthermore, Eva can retrieve and play music to support interventions based on music therapy (MT). MT has been successfully applied in the field of dementia to achieve neuropsychological, cognitive, and social behavior goals at low-cost [6].

Co-Designing Ambient-Assisted Intervention Environments using the robot Eva

We aim to design an Ambient-assisted Intervention System using the semi-autonomous conversational robot Eva (see Figure 3). Based on the model proposed in [10], our AaIS uses behavior data from sensors - located in the environment or worn by the PwD – that trigger appropriate interventions in the environment performed by the robot Eva. Moreover, the caregiver can enact an intervention via the robot using a remote app to control the behavior of Eva. The robot can enact an intervention using its autonomous features (e.g. small talk, jokes, games, and play to music). Thus, social interaction is the main strategy used by Eva.

To establish realistic scenarios where Eva can enact successful interventions, we followed a co-design process with caregivers from a geriatric residence.

Study Design

Our study employed a co-design approach [16] that involved caregivers in a focus group workshop to evaluate and improve application scenarios of our proposal of AaIS. We used caregivers since they have a better understanding of behaviors and needs from a PwD [5].

	Age	Gender
C1	27	Female
C2	32	Male
C3	25	Female
C4	21	Male
C5*	26	Female
C6*	31	Male
C7*	33	Female
C8*	29	Female
C9**	39	Male

Table 1: Caregivers recruited for the study.

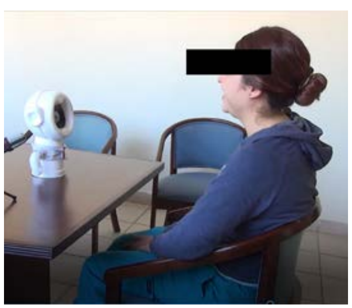

Figure 4: A participant interacting with the robot Eva.

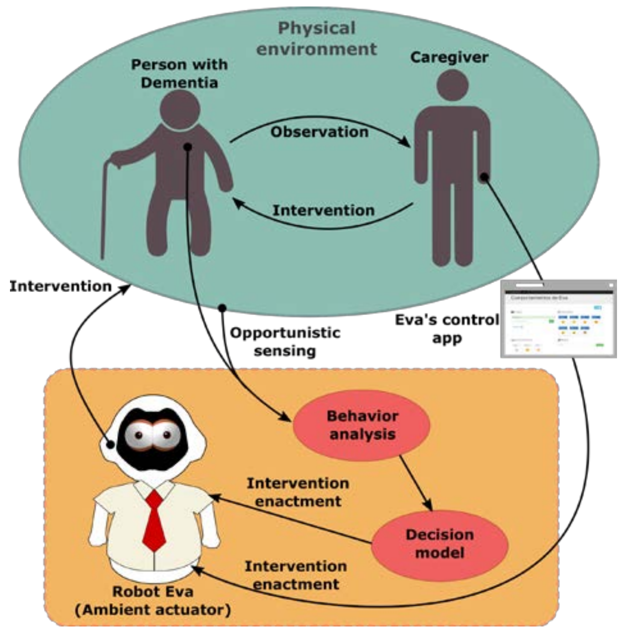

Figure 3: The AaIS monitors PwD and the physical and social environment to detect problematic behaviors and select an appropriate intervention for the robot Eva to enact.

Caregiver's can provide us with reliable information about the interaction of our target users with Eva. The co-design process utilizes the collective creativity of designers working together with non-designers and is well suited for early stages of the design process [16]. We used creativity triggers - artifacts that showed the potential of an AaIS using a conversational robot to facilitate them to explore the design space [12]. The first creativity trigger was the capabilities of the robot Eva. Through an open and individual interaction, the caregivers discovered and explored the features of our conversational robot. The second trigger was a set of four scenarios designed by the research team. The scenarios were used to describe a situation where the AaIS can deploy an intervention via the conversational robot. These creativity triggers promote the discussion, reflection, and interpretation to obtain information about the needs and perspectives of the caregivers in their work context.

Participants

Nine caregivers were recruited, all of them staff members in a geriatric residence. Table 1 summarizes demographic data of the caregivers who participated in phase 1. Five participants participated in phase 2 of the study (one asterisk). One participant only participated in phase 2 (double asterisks).

Co-design Process

Our study adopted a participatory approach. Over two phases of the co-design process the research team and caregivers exchanged their expertise - researchers on technological opportunities and participants on the care of PwD.

Phase 1: Technology introduction. This phase aimed at introducing the technology to the caregivers, to give them a clear idea of the capabilities of the robot Eva. Participants interacted individually with Eva for 5 minutes (see Figure 4). During an open interaction, each participant could explore the capabilities of Eva (e.g. ask date and time, small talk, tell jokes, complete sayings, and search and play a specific music track). This interaction with Eva was the first creativity trigger to familiarize participants with an AaIS and demonstrate some activities that can be used as an intervention to deal with problematic behaviors exhibited by PwD. We asked a couple of open questions to the participants: 1) What do you think about Eva? 2) Do you

Figure 5: Participants of the focus group co-design workshop.

think that Eva can enact an interaction with a PwD? The transcript of these questions and recorded videos were analyzed using an open coding scheme to identify information and opportunities to improve the design and behavior of Eva.

Phase 2: Evaluating scenarios. We described four application scenarios for the AaIS: 1) based on personalized conversation for anxiety; 2) using music therapy to distract and to relax; 3) conversation to deal with depression; 4) using a spatial and temporal orientation and storyteller to handle wandering. We made these preliminary scenarios based on information obtained in a previous contextual study [3]. Scenarios described situations of what, when and where the robot can enact an intervention. The interventions are based on the current capabilities of the robot, but the inference of a problematic behavior is based on literature or previous work by our research group. This phase aimed to address a key objective of our research, establish realistic scenarios to design and implement interventions with the conversational robot. Thus, the first 45 minutes of our focus group design workshop were to expose the four scenarios to obtain comments, feedback and new ideas from the participants (see Figure 5). The discussion was promoted by four questions: 1) Is this a realistic scenario? 2) Have you used this kind of intervention strategy in your day-by-day work? 3) What elements of the scenario are not realistic? 4) What would you change in the scenario to make it more realistic? One of the scenarios used is described below.

Scenario 4. *Mrs. Pilar experiences sleep disorders. The caregivers usually spend time with her during the night until she gets to sleep. However, at dawn, Pilar often wakes up and starts to wander inside the house. Hence, the caregivers must be alert to prevent her from falling or disrupting the sleep of other residents. Eva monitors Pilar's sleep using its microphone and a smart bracelet that Pilar wears and is able to detect if Pilar is getting up. When this behavior is detected in the middle of the night, Eva initiates a conversation with the resident. Pilar asks: Where am I? What time is it?, Is it time to have breakfast? Eva tries to convince her that it is dawn and it is time to sleep. Eva assumes the role of a storyteller to try to get Pilar back to sleep. Moreover, the robot can play background sounds to help her relax. Pilar relaxes and goes back to sleep. If Pilar continues to be agitated, Eva sends a signal to the caregivers to enact a human intervention.*

After discussing the scenarios, participants were asked to envision new scenarios and propose improvements and/or new features for Eva. After the workshop, we reviewed field notes, audio transcripts, and workshop video. Using an inductive approach [18], data were coded and categorized into intervention activities, situations, and Eva's features.

Results

We first discuss situations and intervention activities which participants proposed based on the preliminary scenarios. Second, we showed the strategies and recommendations that participants envisioned for a realistic AaIS. Hence, we discuss improvements and/or new features for our robot prototype and other technologies. Data gathering was conducted in Spanish - native language of all participants, thus we translated some quotes to English to illustrate our results.

Personalized Interventions

Each person experiences dementia in a different way, even the same person can experience the disease in distinct ways during the same day. Moreover, gender, educational level, interests, and sociocultural background influence the personality of each PwD. Thus, some interventions may not apply to all persons who suffer dementia. Participants agreed that the robot interventions must be enacted based on the level of dementia and personality of the individual:

"*Eva must be programmed for each patient. Eva's behavior should be based on the person with whom it interacts.*" [C6]

"*Each of us implement a strategy in a distinct way, although we always follow the basic instructions and recommendations from our training. I try to remember talks with them [PwD], thus in a new conversation, I use that knowledge to achieve a better interaction*." [C6]

Listen more, talk less

In Scenario 1, the robot listens to a PwD who recalls an event. While Eva engages in the conversation, the PwD is motivated to talk more. Listening to the PwD is a common strategy used by the participants in their everyday work:

"*The interaction is ok. Eva is the main actor in the interaction. But, the main actor should be the person with dementia. I think Eva must listen more and talk less*." [C4]

Music as an essential feature

Scenario 2 proposed a music therapy enacted by Eva. Caregivers agree with an intervention based on music because it is one of the most effective strategies that they implement to deal with problematic behaviors:

"*If [resident name] listens to music during the day, she is another person. If she is listening to music, she relaxes and soothes*" [C9]

"*Every day we put the music channel on TV. Sometimes they recognize some song and they sing that song all day*" [C5]

The caregivers made some recommendations to make the scenario more realistic. Thus, the participants envisioned a robot that can recognize fragments of a song and play it:

"*They [PwD] do not sing all the song because they only remember some fragments. They often do not remember the name of the song. It is necessary that Eva can recognize a lyric fragment of the song to search and play it*" [C5]

Agent for orientation therapy

Temporal-spatial disorientation is a common symptom in PwD. Repetitive questions about place and time are frequent in the residence. Caregivers implement simple activities related to an orientation therapy such as placing clocks and calendars around the residence and answering repetitive questions from the residents. They foresee a technology like Eva assisting in an orientation therapy for PwD:

"*If a patient gets up, our first strategy is to tell her that it is not a good time to get up from the bed. If Eva can provide time and space orientation, then the robot would help us a lot.* "[C9]

A storyteller to distract and relax

Another effective strategy is to tell them stories related to past, pleasurable memories. Caregivers express that a storyteller could modify the mood or behavior of the PwD, and it is a strategy they currently employ to distract and to relax to some residents:

"*[Resident_name] enjoys when we talk about Mexicali [her birthplace] and what happened there. When she stays in her room, we can program the robot to talk and tell stories about Mexicali, and she [PwD] will be happy and calm for a certain time*." [C8]

An embodiment to promote social presence

Caregivers agreed that it is necessary for the conversational agent to have an explicit social presence to interact with PwD. Hence, the robot needs to have explicit features of personality like an embodiment or face:

"*Many of our residents do not have the experience of talking to devices. I do not think that they can interact with a speaker without personality. However, they sometimes talk to dolls or stuffed animals. If you use an embodiment with face, eyes, and hands, then PwD could perceive an entity and interact with it*." [C9]

Improvements and/or new features for Eva

To implement interventions/strategies envisioned by the caregivers and to improve activities that were implemented in the first prototype of our robot, we will need to add more technical, and behavior features to the robot Eva. We describe below some features to be implemented in the prototype in the short/medium-term.

Enriched vocabulary. The robot should use simple utterances to talk with PwD. However, to avoid monotonous and boring talks, it is necessary to enrich the utterances with affective terms or an extended vocabulary.

A strong accord between emotions and context. The participants reported that often facial expressions do not coincide with the speech of Eva. Thus, PwD can be confused with this inconsistency:

"*I asked for a song, and she shows me a loving face. That is incoherent and can be strange for them* [PwD]" [C5].

Explicit control over interventions. The behavior from PwD is very variable. An intervention that has worked for weeks could be ineffective or even negative at a later time. Thus, the caregivers must control the robot to modify the intervention, and to execute smooth aborts when if conversation becomes inadequate.

Speaker recognition. All participants agreed with personalized interventions. Eva should recognize the speaker and change the personality, topics of conversation, or vocabulary accordingly.

Diversity of personalities. Diverse personalities for Eva can facilitate its adoption. Thus, the robot should be able to adopt different faces, voices, gestures, and embodiment.

Preliminary Intervention

We conducted a preliminary intervention based on the key findings obtained. Specifically, this intervention was

Figure 6: Eva interacting with the first group of PwD.

Figure 7: Participants of the second group are singing with Eva.

based on Scenario 2 of the co-design study. We implemented an intervention based on an active music therapy - participants are actively involved in musical improvisation with instruments or voice [19]. Singing in a group setting can improve social skills and foster awareness of others, furthermore singing may encourage reminiscence and discussions of the past, while reducing anxiety and fear [19]. During a session with a small group of PwD, Eva encouraged participants to sing.

Caregivers proposed candidates for the intervention with Eva. We conducted two sessions (see Figures 6 and 7) with two groups of three residents who suffer from dementia. During the intervention, a caregiver introduced the robot Eva to the participants and asked Eva to play a song. During the session, Eva paused the song and motivated participants to sing or answer questions related with the song being played. When Eva did not understand an utterance from a participant, an operator used a remote control application to recover and give the appearance of a seamless interaction. The intervention was conducted in the living room of the geriatric residence. Sessions lasted 24 minutes and 35 minutes respectively and were recorded on video.

During the first session, Eva played seven songs (four different songs, as the residents asked Eva to repeat one song three times). For session two, Eva played nine songs (eight different songs), one of them was played twice. The living room is a common area in the geriatric residence, thus during the sessions, two residents joined the first session while one resident joined the second session. Also, one resident participated in both sessions, since she requested to stay there arguing that she was enjoyed the therapy. A resident that was in the living room but not participating in the interaction, started to sing with one of the songs. This surprised the caregiver and fellow residents since she seldom speaks at all. All participants sang at least one fragment of one of the songs. At the beginning of the intervention, participants did not talk to Eva directly, but as Eva talked, answered, and played songs to them, the participants talked and engaged with Eva.

Conclusions

We engaged caregivers in the co-design of a conversational robot to interact with PwD. Taking into consideration the skills of our first prototype, caregivers proposed improvements for situations and strategies to be used in realistic scenarios, also they proposed additional features for the robot. Several of these recommendations were implemented in an updated version of the robot Eva. A preliminary evaluation with six PwD provides evidence that the PwD were able to adopt Eva, interact with the robot without explicit intervention from the caregiver and enjoyed the session. We will conduct an in-depth analysis of the intervention and extend our study to include more sessions and participants.

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