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Delft University of Technology

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Design and Development of a Physical and a Virtual Embodied Conversational Agent for Social Support of Older Adults

Marieke M.M. Peeters; Vivian Genaro Motti; Helena Frijns; Siddharth Mehrotra; Tuğçe Akkoç;
Sena Büşra Yengeç; Oğuz Çalık; and Mark A. Neerincx

Abstract— Populations in developed societies show an increasingly higher life expectancy across the globe. To support older adults to live longer and healthier lives in the familiar surroundings of their homes, technological developments, such as robots and avatars, have a great potential.

To investigate long-term interactions between older adults and a “bi-bodied conversational agent” (an agent that has both an avatar and a robot embodiment), a user-centred design approach was employed in the design and development of a conversational agent. Firstly, the requirements of the agent were elicited through a set of focus groups with the target users – older adults.

Then, the agent was iteratively designed and implemented: a robot body and avatar body were created. Finally, a wizard-of-Oz control panel was created to control and compare each of the two bodies. Current research outcomes describe the elicited requirements baseline of a bi-bodied conversational agent for older adults. Future research involves the use of this set-up to investigate long-term interaction between older adults and a bi-bodied conversational agent.

Index Terms— Robot; Social Agents; Avatar; Wizard of Oz; Conversational Interfaces; Older Adults; Human Computer Interaction; User Centred Design; Embodied Conversational Agents

I. INTRODUCTION

OVER the next two decades, almost 20% of the total population in developed countries will be of age 65 and above. As a result of the rapidly growing population of older adults and lack of caregiving resources, governments and

healthcare providers are eager to find new ways of providing high quality elderly care, while reducing the associated costs.

One promising direction in finding a solution to the problem of quality care for an increasingly aging population is the use of innovative technology. Robots and avatars are good examples of technological solutions with a large potential in this field. By integrating sensing, mechatronics, and communication technologies, they are able to support older adults during their daily activities, facilitating connectedness between older adults and their social environment.

Despite the large potential that technology has for the aging population, previous research has shown that older adults are usually slower than their younger counterparts to adopt novel technologies [1,2]. This hesitation, potentially caused by inaccessible or user-unfriendly solutions, excludes a large part of older adults from benefiting from technology. In fact, regardless of their purposes –medical, social, or household–, to assure higher adoption and acceptance rates, future technological solutions for older adults need to carefully consider the needs, requirements, and capabilities of the elderly generations [3,4,5].

One of the design challenges in technology for older adults is having a unified definition for the target group. In the literature, the age used as a cut-off-point for elderly people ranges from fifty [6] to eighty-eight [7]. This wide age range challenges researchers to address diverse needs of older adults who are among the largest but most under-represented user-groups in scientific studies.

Previous research indicates that embodied conversational agents (ECAs) (e.g. robots or avatars) are especially promising in supporting elderly to age in their home environment [8,9,10,11,12]. ECAs can offer older users a natural and intuitive interface to interact with complex technology –such as smart homes, web applications, and so on– thereby facilitating interaction between the elderly and the technology [13]. An ECA can adopt many forms and embodiments, yet for the current purpose of designing an intuitive interface for older adults, two formats stand out:

- 1) a virtual body in the form of an avatar
- 2) a physical body in the form of a robot

The main difference between these two options is that a robot is physically present in 3D space, as a tangible interface, whereas a virtual avatar is only present on a screen. As a result, a robot and an avatar also have different affordances: an

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avatar is able to provide help in a virtual environment, whereas a robot is able to provide help in a physical environment. Yet, in addition to the inherent differences in their capabilities, having a physical body may also affect the user-agent relationship in unforeseen ways. Previous research suggests that, compared to the avatar interaction, the interaction with a robot is more engaging [14]. Furthermore, a robot is often perceived as more helpful and enjoyable, as something with a social presence that exists and is experienced as real [15,16,17]. Research with university students found that people had more positive interactions and engaged more with relaxation exercises when these were presented by a robot with an embedded screen, as opposed to the exercises being presented on a tablet [18]. Yet despite the seemingly positive effects of robotic ECAs, most of the available systems developed for older adults still involve screen-based interfaces instead of robots [19].

The appearance of social agents – be they avatars or robots – is often human-like or animal-like, and it can be challenging to find the right balance when trying to offer a familiar and intuitive communicative interface without raising too high expectations or becoming unsettling [20,21].

An interesting option to get the best of both worlds, is to create a conversational agent that can take control of two bodies, one of which is a virtual avatar body that can help a user in the virtual environment, and the other a robotic body that can aid the user in his/her physical environment. Older adults prefer to interact with ECAs through more natural and familiar modalities [22]. The usability of both bodies may vary according to the needs of the environment, but the user's perception of the agent can be established by having similar characteristics and functions in different bodies. It is supported that users perceive such an agent as a continuous identity even if it migrates between different embodiments [23].

Despite a large body of research on social robots, and a consensus on their large and promising potential to help older adults to age in place, there is a limited understanding on the perspectives of older adults about these technological solutions, especially concerning the benefits and drawbacks related to ECAs in the form of a virtual agent or avatar versus ECAs in the form of robots. Therefore, the *research objective* of the work described in this paper is to design and develop a research set-up that enables researchers to further investigate long-term interactions between elderly people and ECAs with both a physical and a virtual body. Having a physical and a virtual solution of a conversational agent permits researchers to conduct user studies with older adults to assess multiple quality criteria, including the acceptance and usefulness of the solutions, as well as the costs and benefits associated to each form.

This paper is structured as follows. Section II describes related work on the design of avatar and robotic embodiments for ECAs. Section III introduces the research approach. Section IV presents the design of the agents as envisioned by the researchers. Section V describes the method employed to elicit a list of user requirements that helped shape our design of the ECA. Section VI presents the outcomes of the research. And Section VII reflects on the work described in this paper, by discussing the implications of the findings, plans for future

research, and concluding remarks.

The key contributions of this research include: (1) a theoretical contribution (design decisions and user study results), (2) a computational solution (virtual agent), and (3) a physical prototype (robot).

II. RELATED WORK

Previous research has explored and compared various available ECA-based solutions for elderly users in terms of, e.g., feasibility of implementation, usefulness, and user acceptance. A review of the literature on ECAs for elderly reveals the following state of the art in terms of human factors and affordances that are of relevance to the design of ECAs.

Bennet & Šabanović (2014) investigated human-like robotic faces [24]. Their findings suggest that eyebrow, eye and mouth movement are sufficient for recognition of emotions. Additional neck movements may further increase correct recognition of expressed emotions. A robot design might not be acceptable if users perceive it as “childish” [25]. Volonte et al (2016) investigated a cartoon-shaded versus a sketch-like versus a more realistically shaded virtual avatar. They found that the rendering of the avatar has an effect on measured affect and the way participants perceived the personality of the avatar [26]. Paauwe et al. (2015) suggest that perceived affordances (i.e. realism in terms of participants being able to imagine using the robot in the real world) are more important than modelled realism (in terms of visual similarity to existing “agents” like nurses) to the usability of a robot [27]. Wu et al. (2014) conducted focus groups and semi-structured interviews with elderly with mild cognitive impairment to explore their attitudes toward assistive robots. They found that many of the participants were hesitant to the proposed technology and its functionalities, arguing that similar functionality was already available on other devices. The participants could not imagine using robots themselves, but could see some use for elderly who were more impaired than they were. Wu et al. suggest that in order to maintain elderly people's autonomy, it is better to have robots fulfil a supplementary function, rather than replace human functions [28].

A recent EU-financed (h2020) research project called PAL4U¹ uses a robot as well as an avatar of the robot to motivate children with diabetes to better manage their health [29]. PAL uses the virtual robot to allow for the children to communicate and interact with the robot through their smart devices, resulting in lower costs. When the children come back to the hospital for checks and follow-ups, the real robot is there using a user model that is shared with the virtual robot, to ensure consistency in its behaviour toward the child. The PAL project illustrates how two bodies can be complementarily used in different settings and for different purposes: at home the virtual assistant helps children to fill out their diary, while at the hospital the physical robot plays games with the children.

¹ <http://www.pal4u.eu/>

III. APPROACH

To ensure that the users' perspectives are considered from an early design stage onwards, this study followed a user-centred design approach. Four design phases were combined: 1) conceptual design (framework and requirements), 2) brainstorming, 3) prototyping, and 4) user studies (questionnaires and focus groups).

The methodology for our design study, is inspired by the situated Cognitive Engineering (sCE) method [30,31]. The sCE method aims to support the design of intelligent human-computer interaction. It focuses on the iterative specification and refinement of a design rationale: a comprehensive argumentation underpinning the design choices made throughout the design process. A design rationale is situated in the task domain (operational demands), founded in theories from human factors, implemented in a technological solution, and evaluated through empirical evaluations.

The design process took place through a number of rapid iterative cycles, each cycle taking the outcomes of the previous cycle to refine the design ideas and test the outcomes with the end users. In the first stage, various possible designs were created by the research team based on an initial functional framework. In the stages that followed, the design ideas were incrementally refined and evaluated with the target users through a questionnaire and four focus groups. The stages are presented and discussed in detail in the next sections. Based on the end users' perspectives gathered throughout the design process, a semi-functional high-fidelity prototype of the ECA was built. This study received approval from the Human Research Ethics Committee from Delft University of Technology.

IV. DESIGN PREPARATION

The current study focuses on the design of a bi-bodied conversational agent for older adults. First, a functional framework (Figure 2) was collaboratively defined by the research team. This framework describes the basic components and functionalities of the to-be-developed set-up. As input controls, the user's behaviours are detected through sensors, e.g. a microphone (for audio and speech analysis), and proximity sensors (for motion sensing). Seeking to assess the feasibility of the two prototype formats, as well as their benefits and drawbacks, the following design requirements were elicited.

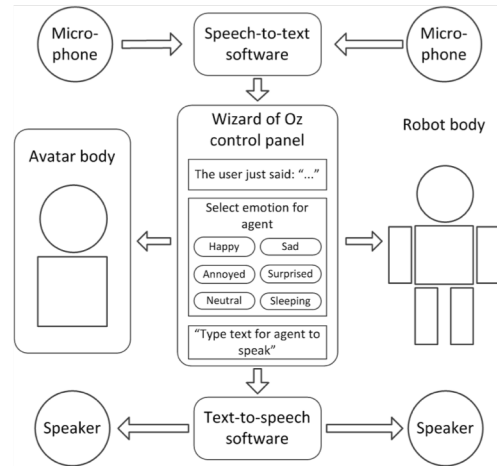


Fig. 2. Functional framework of the envisioned application enabling a comparative analysis of an embodied conversational agent for older adults with two embodiments (a virtual and a physical body)

A set of requirements, including features available and quality factors, were discussed in the early development phases. The functional requirements for the solution include:

- The robot body and avatar body should enable control through a Wizard-of-Oz (WoOz) [32] technique (i.e. unbeknownst to the user/participant, a human researcher mimics the envisioned interaction with the user before actually implementing the software or artificial intelligence needed to automatically produce such behaviour) ensuring a consistent behaviour for both embodiments:
 - o The WoOz should be able to instruct the robot/avatar to talk
 - o The WoOz should be able to change the facial expression of the robot/avatar
 - o The WoOz should receive information about the conversation, e.g. facial expression of the user, contents of the conversation

The non-functional requirements for the solution include:

- The two prototype formats (i.e. the avatar body and the robot body) should be consistent in a way that users can identify the similarities between the two embodiments
- The solutions, including the agent bodies, voice, and facial expressions should be acceptable and likeable by elderly users.

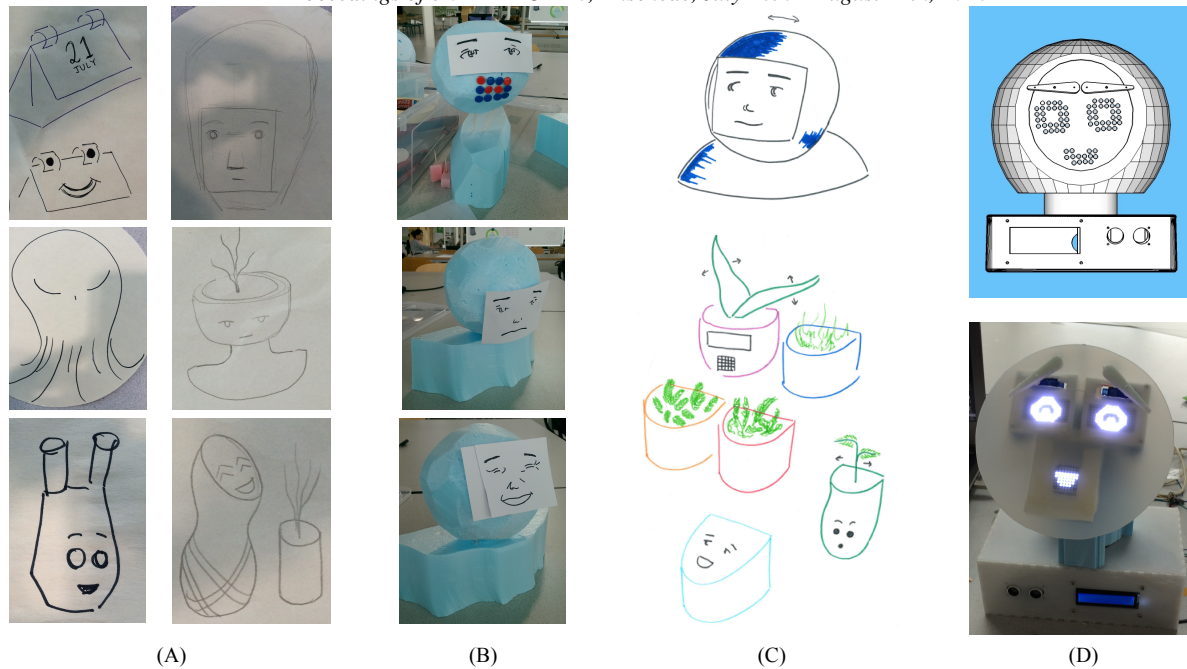


Fig. 1. Various designs and prototypes: (A) Six low-fidelity paper-based designs, ranging from objects, animals, abstract, human-like, and plant-like shapes (B) Three foam-based prototypes illustrating 3D sculptures of potential body formats (C) Pre-final designs for discussion in focus groups, human-like and plant-like designs, (D) 3D model of the final design (top) and final prototype (bottom)

Based on the initial framework, a brainstorm session was conducted by the research team, to propose and discuss the advantages and drawbacks of various alternative looks for the ECA design. The research team was composed of people with different backgrounds: computer science, human-centred design, electrical engineering, cognitive science, psychology, mathematics, and fine arts.

The brainstorm session was followed by a design session, in which 2-D paper-based prototypes (Figure 1 A – calendar-like, human-like, animal-like, plant-like, abstract and object formats) and 3-D foam-based prototypes (Figure 1 B – robot head and body compositions) were built to illustrate different ECA formats. Sketches of a human-like and a plant-like ECA were generated and discussed in the early design stages of the study (Figure 1 C).

Six paper-prototypes (Figure 1A) were sketched and discussed during a brainstorm session (the look ranged from human-like, to animals, plants, and abstract shapes). During the session the research team analysed the advantages and disadvantages (e.g. mobility, placement in the home, acceptability, aesthetics, stigma, associations, etc.) of each design regarding potential familiarity, comfort, costs, meaning, and ease of use. The researchers then selected two designs to be discussed in focus groups with the target users: a human-like design (Figure 1C above) and also a plant-like design (Figure 1C below).

V. USER STUDIES

A. Method

The design decisions for the solutions proposed were guided by four complementary design aspects, namely:

- 1) The appearance of the bodies, including the aesthetics, dimensions, textures, colours, and visual features. Decisions regarding these aspects were made through thorough discussions of the prototypes among the research team and potential users;
- 2) The functionality of the bodies, i.e. suitable and/or useful purposes of the ECA for older adults, in terms of features and functionalities. To decide on the possibilities, a set of user studies was conducted (combining questionnaires and focus groups);
- 3) The creation of the two bodies (physical and virtual one), decided after a cycle of proposal, test, development, and preliminary evaluation of the robot and the avatar; firstly discussing the feasibility of the construction (hardware and software aspects), given the resources' constraints of time, design, and budget, then focusing on implementation and testing;
- 4) The software for the WoOz panel: logical aspects (algorithm), technical implementation, as well as the integration, compatibility, languages (Dutch and English), and scalability aspects. All thoroughly discussed by the design team, resulting in a combination of existing tools (e.g. Pandora bot and MyRobotLab) and customized software solutions.

1) Appearance

Prototypes made out of paper and foam were created to explore different shapes, dimensions and facial expressions for the robot. Figure 1A and 1B illustrate alternative face and bodies for the robot as considered in the early stages of the project. The design of the appearance was then further refined through three research steps: a brainstorm session with the team, a questionnaire, and four focus groups. Each step is further explained in the following subsections.

a) *Questionnaire*

To gather general insights about the older adults' perspectives on ECAs (appearance, potential functionality, and previous experience), we conducted a preliminary online survey with 22 participants (11 men and 11 female, $M_{age} = 67$ years, $SD_{age} = 2.5$ years) from the Netherlands, Turkey and India). The questionnaire was distributed among family, friends, friends of friends, and through social media. The questionnaire provided a brief explanation of what an ECA is and how it might be of use to support in daily chores around the house. People were then asked whether they have any chores around the home that they could use some help with. Participants responded by mentioning various daily routines they engage in, and how they use calendars, mobile apps, sticky notes, and the placement of reminder objects around the home. People were then shown four of the designs created by the team of researchers, i.e. the humanoid, the animal-like, the plant-like, and the abstract design (also see Figure 1A). On asking about the prototype of the robot participants' opinions varied on what kind it should be: 31.8% preferred it to be humanoid, 45.5% for animal look, 13.6% for plant look and the remainder, 31.8% preferred it to be abstract.

b) *Focus Groups*

To gather specific feedback from older adults concerning existing ECAs and potential design formats, we also conducted four focus groups. As mentioned in the introduction, we acknowledge that the user group "elderly people" is a large and highly diverse group of people. For this reason we included people from various ages (60-85), men and women, and people who are still active and healthy as well as people with somatic problems. In total, 23 older adults participated in the four sessions (14 men and 9 females, $M_{age} = 71$ years, $SD = 2.5$ years) from the Netherlands and Germany. The participants were recruited through their garden club, via word-of-mouth, and through a healthcare organization in the Netherlands. Participants signed the informed consents before the sessions started. All focus groups consisted of different participants. Most of the participants in the first two sessions were highly educated (university level) and did not have any important cognitive or motor impairment, although some participants had hearing aids and visual impairment natural to their age. In the third and fourth focus group, participants were not highly educated and did show more serious somatic impairments such as multiple sclerosis.

The first two focus groups mainly focused at assessing the acceptability of the two paper prototypes (i.e. humanoid vs. plant/object – Figure 1C), however, before assessing the two designs with the participants, the researchers provided an introduction to the topic, discussing what constitutes a robot or avatar, and what purposes they might serve. After all participants had a clear idea of what a robot or avatar might be able to do for them, the two designs were shown and evaluated with the target group.

The first prototype showed a humanoid face on a screen that was embedded in a sphere (named astronaut-like design). This sphere represented the robot's head attached to a neck to connect the head with the robot's body. Participants were informed that the facial expression of the robot could change

depending on its programmed mood. The second prototype showed robots that were plant-like or object-like (vase-like). Participants expressed a preference for the first prototype and immediately rejected the robotic functions in unanimated objects like vases or plants as those would infantilize them. Most participants preferred the human-like design; the plant/object-like design got rejected due to the unnatural communication channel. Participants also reported that a nuanced solution would be preferred, i.e. both the look and the behaviour of the robot should not try to represent a person in all its characteristics, as the older adults would feel uncomfortable interacting with an artificial entity that tries to fully replace a human being.

The script for the first two focus groups covered questions about potential interests and concerns older adults may have about ECAs, provided brief definitions about robots and avatars, and gave examples of existing robots (NAO, iCAT, Flobi, FurHat, and XIBOT) as well as quality factors, desired functionality, appearance and aesthetics (design aspects), personality, motion, and movement features. The outcomes of the first two focus groups indicated that most participants preferred a robot presenting a friendly personality, but they did not feel the need for a robot having a backstory or a strong personality/character. The participants of the first two focus groups also emphasized the importance of maintaining social contacts with *real* humans, which is not replaceable by technology in their opinion. Most participants explained that they would not want an ECA to take over their tasks and responsibilities as this would deteriorate their abilities, unless they are no longer capable of taking care of such themselves. Instead, participants agreed that they would want their ECA to stimulate them to be independent for as long as they can (e.g. to be more active physically or to exercise their memory skills and cognitive abilities).

The third and fourth focus group were conducted with participants who were not highly educated, and who had severe somatic impairments. The participants in these focus groups were largely unfamiliar with robots and what a robotic technology is able to do. In fact, these participants were also unfamiliar with wireless and/or networked technology. As a result, it was difficult to discuss the possibilities of future technology with them – most of the time was spent on explaining to the participants what robot and networked technology is, and what it might offer for them in the future.

Based on the combined outcomes of all four focus groups, we conclude that participants think the usefulness of the robot, as well as its appearance, is strongly related to its purpose, features and functionality. Findings of the focus groups were consistent with related work by, e.g., Mitzner et al. (2010) and Wu et al. (2014): participants were mostly positive about what technology could do for them in terms of functionality, especially when their own capabilities start to decline [28,33]. The functionality of an ECA, in their opinion, varies based on individual preferences. In other words, it is essential to design for personalization and customization of the ECA. Able-bodied users (e.g. without any important impairments) emphasized that their requirements for interaction are very different from users with dementia or any communication

impairments, such as aphasia. Still, common impairments in older adults, including hearing and visual impairments should be generally considered.

2) *Functionality*

The information obtained from the focus groups sessions aided the research team to select a final design: the astronaut-like with a spherical head and rectangular body. As input features, the robot would react to the users' movements and speech, detected through presence and proximity sensors and microphone. Additional functionality of the robot, in terms of output responses includes conversational features and companionship.

3) *Implementation of the Bi-Bodied Conversational Agent*

a) *Robot body*

To implement the robot body, the feedback of the end users (gathered through user studies) and the project constraints were considered (technical aspects, budget, time, etc.). Having a display for a face was discussed. This would have the advantage of it being easy to add extended screen-based functionality and interaction. However, finally, we opted for LED matrices as those would ensure discernibility and visibility of the displayed emotions, even in brightly lit rooms. White opaque material was used to visually connect the LED matrices. We combined these with moveable eyebrows to further enhance the perception of the digital agent as being physically embodied (as opposed to embedding the on-screen avatar in the robot head).

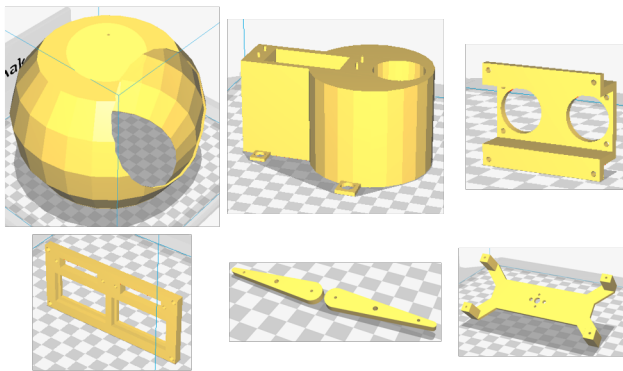


Fig. 3. Three-dimensional models of the head of the robot skeleton (skull, neck, proximity sensors, eyes, eyebrows and support piece).

Three-dimensional models of the robot skeleton were generated using SketchUp, integrating structural pieces (brackets for the eyes, eyebrow, neck, and skull) with external parts (robot body, eyebrows), and electronic components of the robot (Figure 3). A laser cutter was used to create the body box, with dimensions sufficiently large to house the electronics. The head skeleton, eyebrows, brackets and robot neck were 3D-printed in an UltiMaker 2. The components were assembled with screws to ensure a sturdy integration. Table 1 describes the list of components used in each robot part. Four Arduino Uno boards were used to implement and integrate the behaviours of the LED matrices (eyes and mouth), sensors, and neck movements.

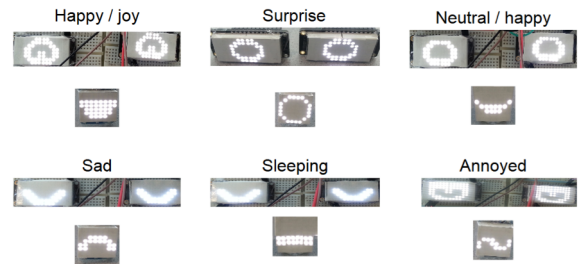


Fig. 4. Six facial expressions of the robot.

Based on the research conducted by Bennet & Šabanović (2014) [24], we decided to express the robot's emotions through facial expressions combining different movements for the eyebrows, eyes, and mouth (Figure 4). Also, bi-dimensional head movements were defined – horizontally (left and right movements), and vertically (up and down movements).

TABLE I
FINAL PROTOTYPE COMPONENTS OF THE ROBOT

Part	Material	Electronic Pieces
Head	- 3D printed globe - Paper mache finishing	
Eyes and Eyebrows	- 3D printed brackets	2 mini servo motors 2 8x16 LED matrixes (white) 1 Arduino Uno board
Mouth	- 3D printed brackets	1 8x8 LED matrix (white) 1 Arduino Uno board
Neck	- 3D printed structure - 1 tilt/pan bracket	2 normal-sized servo motors 1 Arduino Uno board
Body	- Laser cut rectangular box of white 3mm polyoxymethylene	1 LED display 2 proximity sensors 1 Arduino Uno board

b) *Avatar body*

A virtual avatar was created using the Crazytalk software by Reallusion [34] to mimic the behaviour and functionality of the physical robot. The image of the physical body of the robot was rendered to produce the virtual avatar using coordinate dissection, i.e. mapping anchor points of the image to a skeleton used for the automatic generation of facial expressions. Pictures of the avatar are presented in Figure 5.

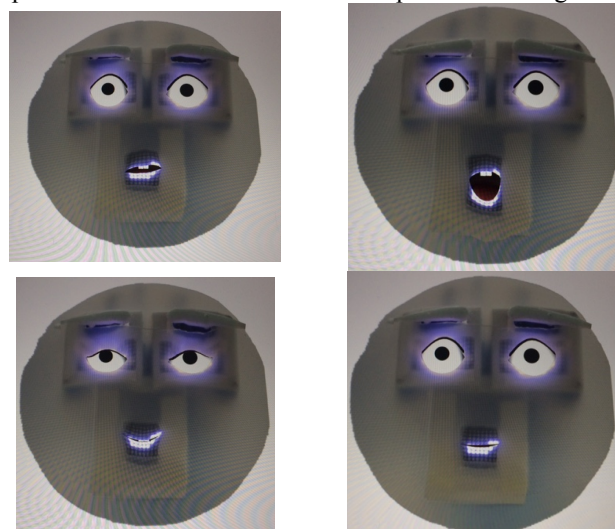


Fig. 5. The avatar, based on the robot, created with CrazyTalk

4) WoOz panel

We also developed a simple GUI for the Wizard-of-Oz to control either of the bodies, depending on which body is connected to the control panel (Figure 6). The whole panel was designed using MyRobotLab software [35]. Part of this control panel is also the functionality of “talking” to the user through a speaker set (independent of robot body), by typing text into the control panel and using text-to-speech synthesis software. ALICE 2.0 bot AIML scripts were used for partially automated conversation so as to relieve the Wizard from replying to all conversational utterances. The avatar and/or robot actions can be controlled by the Wizard-of-Oz using the

Our results also show that older adults are more likely to accept the ECA technology when a clear need is identified and trust is built. In this study, we explored the feasibility of building and employing ECAs for the specified user population, setting the design foundations for future projects in the domain, and building a low-cost portable ECA solution to enable further evaluations (as described next).

As future work we plan to complement the evaluation of the technology created, exploring additional features of the robot, and gathering more users’ insights for future design directions. We plan to refine the prototype built, optimizing and automating functions that are currently semi-automated. We plan to build a comprehensive documentation of the solution,

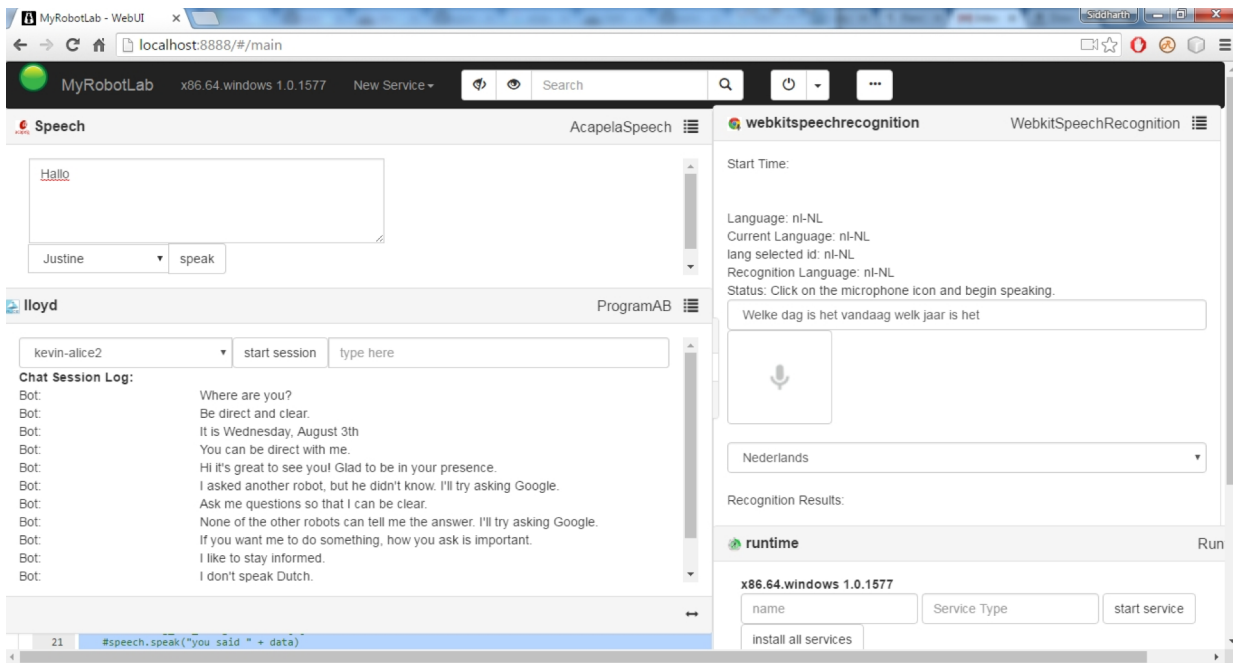


Fig. 6. MyRobotLab was used to develop the Wizard-of-Oz Panel

WoOz panel as described in the study by Cheong (2011) [36].

VI. DISCUSSION AND CONCLUSION

The key contributions of this work include: a conceptual framework for designing, evaluating and comparing two ECA formats (robot and virtual avatar); a computational component, integrating existing software and customized algorithms for speech recognition and conversational features; and a physical prototype, i.e. a robotic prototype for social communication activities with older adults. This study also provides insights in the perspectives of older adults upon embodied conversation agents (ECAs) as technological solutions for social communication. The current paper covers both design and implementation challenges to gain a deeper understanding of the needs and preferences of older adults when interacting with ECAs. Following the inclusive design principles we incorporated the potential users in all stages of design, development, and evaluation. Our results indicate that in principle older adults hesitate to adopt ECAs as technological solutions, for multiple reasons, ranging from: fear to lose or deteriorate their existing abilities and social contacts, lack of purpose or need, reliability issues and cost.

to enable replication of the project by other research teams. Concerning the virtual agent, we plan to synchronize the updated version of the design with the current avatar, and as such conduct future evaluations and comparisons investigating the benefits, drawbacks, and specific advantages of a virtual agent vs. a physical agent, as perceived by older adults.

Creating and designing an avatar/robot for elderly users is a complex process that requires a lot of thought and experimentation. The combined approach of participatory design involving focus groups in different steps of the design process and micro-analysis of the users’ interaction with the system has shown that the users – senior citizens – are not generally afraid of autonomous systems. In fact, we conclude that users’ attitudes actually improve after interacting with the system.

The main lessons learned through this study is (a) how important it is to have a clear idea of the study population, as older adults may large vary on their needs and interests to have and/or use an ECA, and (b) that the research approach (sCE method [30]) used throughout this study is well-suited for guiding the design process, incorporating user requirements, and evaluating those requirements with the

target group. This rapid development of incrementally more complex prototyping and evaluation may benefit other research projects, especially when designing for understudied groups of people, involving new and innovative technology, situated in specific and complex task domains and environments.

As design considerations for a system that would be socially acceptable, participants mainly stressed that the robot should be functional. Robot functionality is highly dependent on the target individual. This entails that a high degree of customizability is needed. Every individual needs a different design solution depending on their needs and possible impairments. Generally, people preferred a somewhat humanoid way of expressing emotions via a face, with individual people's preferences ranging from abstract to very human-like. More research is needed to determine the acceptability of the current system, as well as research determining if participants can recognize the emotions as programmed.

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