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Social robotic application to support active and healthy ageing

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Abstract— **With the world population ageing and with the number of healthcare users needing assistance and support increasing, healthcare is becoming more costly and, as such, the need to optimise and support independent living for older people is of paramount importance. This paper reviews the user requirements and challenges that are relevant to older adults who prefer to age healthily at home, and how socially assistive robots (SAR) can be used to help them. The main focus is placed on the social robotic application developed for the H2020 SHAPES project to promote Smart Living Environment for healthy ageing. The solution is based on the newest PAL Robotics' robot ARI, a high-performance social robot and companion designed for a wide range of multi-modal expressive gestures, gaze and personalised behaviour, which is integrated via several Digital Solutions developed within the SHAPES project to improve human-robot interaction and user acceptability for independent living support tasks. The validation process will take place over the coming months at Clinica Humana (Mallorca, Spain), which is a private clinic that provides hospital care to retirement homes, communities and home-bound patients. A description of the scenario definition is presented in the paper, together with the validation plan that will be executed during the pilot assessments and the measures that will be taken to improve user engagement.**

I. INTRODUCTION

The world's population is aging. What is more, there is increased social isolation, with over half of people over the age of 75 living alone with having limited interaction with people, as well as an inability to function independently [1]. Furthermore, there is an insufficient number of formal and informal caregivers, and the cost of healthcare is increasing [2]. Considering that older adults prefer the option of healthy ageing at home, it is essential to focus efforts on developing new assistive technologies [3]. Socially assistive robots to assist the elderly could have a positive financial impact as well as promoting successful ageing with a view to providing personalised care [1]. In order to remain independent, older people often need assistance in remembering appointments, taking medication, keeping physically active and also being further engaged socially in order to reduce the risk of isolation. Moreover, the $COVID-19$ pandemic has also resulted in additional needs and shown the potential of robotics solutions in such scenarios [4].

In the past few years, social robots have been gaining considerable importance, with different projects and social robots focusing on elderly care (Companionable [5], Care-o-Bot [6], Hobbit [7], Pepper [8], EnrichMe [9]). However, their deployment in real-world scenarios is still uncommon and, consequently, the level of acceptance of such solutions remains controversial. This is due to the fact that acceptability of SAR robots by the older population is still low, and consequently their deployment in real environments and use is too. Reasons for this are their technical complexity, and unsuitability for the environments where such robots are deployed [10]. To this end, it is necessary to take a user-centred approach so that end users may actively participate in the robot's design. Through workshops where researchers explain to end-users what the robot can do, they may give feedback on robot design considerations, inclusion or adaptation of certain tasks, etc. [11]. Social robots should be able to express and communicate as naturally as possible using both verbal and nonverbal behaviour, providing human-like interaction to ensure engagement in the interaction, or predict and adapt to the partner needs [13], something that has not been much covered in the above mentioned projects.

The H2020 SHAPES project [14] tries to address all these needs. The project aims to create the first European open Ecosystem to enable the large-scale deployment of a broad range of digital solutions to support and extend healthy and independent living among older individuals. As part of Pilot 1, out of 7 Pilots, this paper presents an overview on how different Digital Solutions (DS) can be integrated in an adapted version of the PAL Robotics' ARI robot [15] to promote Smart Living Environment for healthy ageing. As described in the paper [15] there are clear advantages of such robots over digital assistants or virtual agents specifically in their ability to proactively engage with the user.

The validation process will take place over the next few months at Clínica Humana (Mallorca, Spain). This is a private clinic with more that 7-years' expertise in chronic patient management (currently with over 600 patients), and they provide hospital care to retirement homes, communities and home-bound patients that has a major technological component in the form of telemedicine.

The rest of the paper is organised as follows. Section II

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explains the steps carried out so far to gather user requirements, and mock-ups and highlight the tasks needed. Then the description of the scenario is examined in Section III. Section IV presents the Digital Solutions developed and their integration, focusing on: the ARI robot and its adaptation, solutions for people-related interaction and the technical components for Daily Activities. Section V explains the pilot studies planned and the measures that will be taken to improve user engagement. Finally, a brief conclusion is provided in Section VI.

II. FORMATIVE STUDY FOR USER REQUIREMENTS

In order to develop the prototype, a human centred co-design process has been applied in accordance with the SHAPES project methodology, that takes Personas and User Requirements and gathered obtained in Work Packages 2 and 3 of the project as input definition, similar to [30]. For each of SHAPES pilots, the first phase of the piloting campaign involves specifying the requirements and design of the prototype in more detail, which in this case is developed by caregivers and technical personnel from care-home Clínica Humana, alongside the technical partners involved (PAL Robotics, TREE Technology and VICOMTECH). Namely there are the following types of end users:

- Older people, people between 70-90 years old, living in urban environments. These users live in their houses or in sheltered housing and may receive regular visits, mainly from their family members.
- Caregivers, general practitioners and administrative staff at the sheltered apartment complex.
- CH technicians.

A set of 7 aims have been defined:

- Enable remote temperature monitoring of older adults to detect potential COVID-19 patients
- To remain independent for longer at home (older adults)
- To entertain older individuals and help them engage in different cultural activities
- To make older individuals feel safer and more confident moving around the house
- To help older individuals socialise with friends/family members
- To keep main persona active (physically, cognitive, socially)

Mock-up and prototype validation is the second phase of the SHAPES piloting campaign [30], and refers to simplified visual representations of the actual design of the digital solution, where feedback is obtained through semi-structured interviews.

Specifically for this pilot, the robot ARI was shown to caregivers and older adults between March and April 2021 through video calls - components, demos of several tasks - followed by questions with a view to collecting feedback, some open-ended and others requiring a response according to a 5-point Likert scale or closed yes/no answers. As for which tasks they preferred, the work in [16] acted as a good inspiration for this. In total, the interviews were carried out on 3 personnel from sheltered apartments, 1 on a medical doctor, 1 on an IT technician and 2 with older adults.

Table I summarises the role of each end-user and some requirements indicated. The older adults that were interviewed are 82 and 88 years old. They are especially interested in reminders, for example, being reminded of anniversaries or social events, more than medical appointments - in contrast to caregivers. The feedback collected may not be representative but is still very useful in showing that not all functions are equally preferred. While the caregivers tend to obtain as much information and provide as many activities as possible, the older people tend to select only the functions that match their needs and which they can see a clear advantage.

In terms of robot tasks that users had interest in according to pilot requirements, a decision was made to implement the following, as summarised in Figure 1.

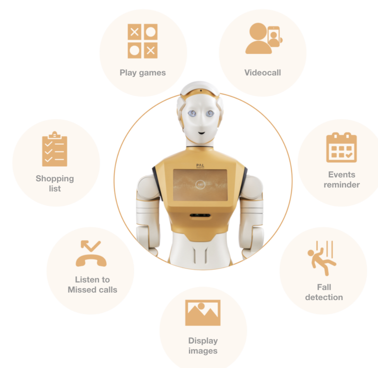

Fig. 1: PAL Robotics ARI robot to be equipped with multiple functions to promote healthy living for SHAPES pilots © PAL Robotics 2021

III. SCENARIO DEFINITION

An example persona that reflects the needs of particular older people at Clínica Humana would have the following scenario: "Helena is an 82-year old woman who lives on her own. She has a caregiver who only visits her a few days a week (2-3). She suffers from some chronic conditions, such as vascular insufficiency, atrial fibrillation, advanced cardiovascular disease with thrombosis in her legs and has some trouble walking. Despite all this, in general terms, her health is good. She likes being autonomous and doesn't like bothering her family and feeling like she's a burden to them. She likes being busy with the activities she likes, albeit mainly indoors due to her limited mobility. Consequently, she spends a lot of time alone and would like a companion that could help remain active and maintain social interaction (for example, through anniversary reminders and videocalls). She likes receiving help when needed, but not for activities that she manages properly."

Considering this scenario and the user requirements gathered in Section II, technical requirements defined result in the following:

TABLE I: End-user, role and requirements

End-user	Role	User requirements
Caregivers and administrative staff	Professional or family members and personnel of sheltered apartments which organise common activites (for example, meals) and assist older people in several ways.	• Receive shopping lists on time • Call older adult • Reminders • Activity report • Fall detection • Meal questionnaires (menu) • To give peace of mind to secondary personas (alerts) • To know if the older adult has fever
Older adult	65+ years, living independently in their own home in urban environments or in sheltered apartments, visited or supervised by a family member or caregiver (including personnel at sheltered apartments) on a regular basis	• Be reminded of different social events, medicines, appointments • Have higher social contact • Entertainment to reduce isolation and boredom • Easy way of interacting

- Face recognition module: unique user authentication to securely access their data and also to provide personalised assistance, with option to introduce credentials on the touch screen (username/password).
- Speech interaction in Spanish: text-to-speech and automatic speech recognition.
- Look for user behaviour, to achieve proactive robot behaviour when delivering reminders.
- Fall detection system, routine, and alert system through a voice note to the caregiver, to increase the feeling of safety for those living alone.
- Temperature monitoring and voice note alert system: especially as a COVID-19 solution
- Entertainment: different games such as Tic Tac Toe, and physical exercise games using the robot's arms, delivered using the robot's multi-modal interface. Games appear to be highly rated by older people, especially those that are familiar with them [17].
- Video calling system
- Personalised reminders and suggestions based on personal needs: medication, appointments, events (movie screenings, birthdays, hairdresser's) and option for older adult and caregivers to introduce new reminders.
- Adapt robot behaviour based on user engagement and provide appropriate robot feedback and proxemics to ensure positive interaction, as emotionally intelligent robots that may understand and adapt to co-partners are shown to be less frustrating to interact with [18].

To achieve multi-modality and proactive behaviour of the robot, there will be two main methods of interaction and for selecting the task to be performed [19]. In the first case, the older adult will approach the robot and ask to begin the interaction using the touchscreen or speech (e.g. "Hello, ARI, can you tell me when my appointment is?'"). In the second case, the robot will proactively search for the user in the apartment according to the reminders set by the caregivers. The Figure 2 shows the flow diagram of the first scenario, for delivering a reminder, indicating the Digital Solutions to be used with a red point, which are better explained in Section IV.

IV. TECHNICAL SOLUTIONS FOR INDEPENDENT LIVING

In order to generate the prototype several Digital Solutions developed inside the SHAPES project will be used, The added value of the ARI prototype is the addition of partner modules in the robot that will add advanced chatbots, speech recognition, emotion recognition, fall detection, and capabilities, to name a few examples, that make it possible to communicate with older users as naturally as possible [13].

A. ARI Robot

The social robot ARI [15], shown in Figure 3, is based on its predecessor REEM [20], with special focus on its human-like shape, autonomous behaviour and advanced human-robot interaction (HRI), in order to enable the robot to better display its intentions, facilitate human understanding and overall increase user engagement and acceptability [13]. ARI is provided with a mobile base, a torso with an integrated Linux-based tablet, two arms and a head with expressive gaze. The robot is designed in such a way as to avoid sharp edges that may cause harm [12].

1) Multi-modal interaction capabilities: In this regard, ARI has a set of multi-modal interaction capabilities through visual, voice and tactile interaction modes that improves the interaction:

- Touch screen interaction: display static images, videos, slideshows (series of images), buttons that trigger other robot actions (with adjustable sizes and colours for increased usability), and HTML packaged content.
- Speech interaction: Text-to-speech capabilities in multiple languages (Acapela Group [1]), with possibility to adjust speed; as well as Google Cloud API for speech recognition.
- Expressive animated eyes: Whenever the robot is switched on, the robot will have autonomous gaze behaviour where it moves the pupils randomly. At present, this behaviour cannot be adjusted, although this will be a matter of interest for the future.
- Animated LED effects in both ears and back torso: Some effects include blinking, and fading from one

[1] https://www.acapela-group.com/

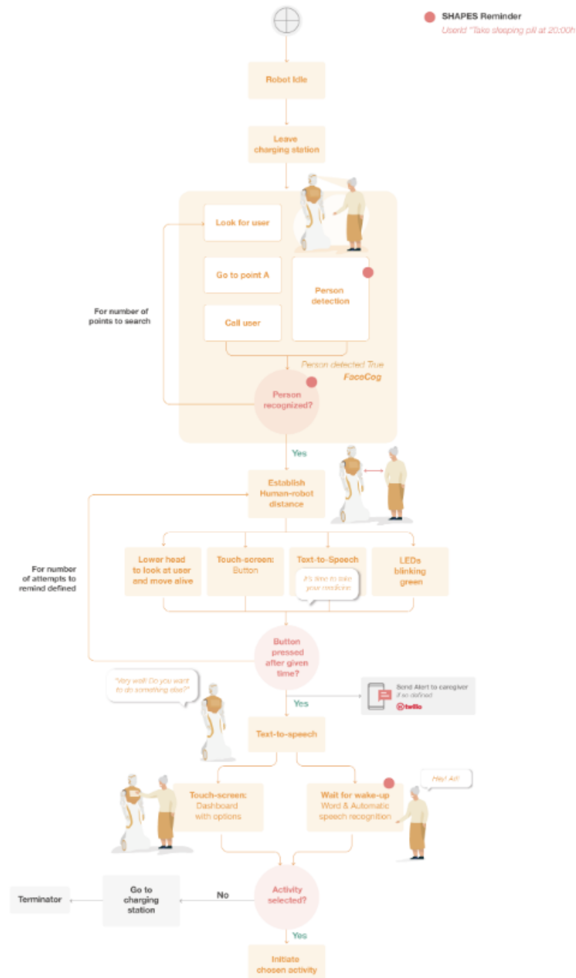

Fig. 2: The flow diagram of the delivering a reminder scenario © PAL Robotics 2021

colour to another, to indicate battery level, emergency status and other robot's internal state and intentions

- Gestures: New motions can be created using the motion builder [2], shown in Figure 4, enabling non-technical users to create or adjust already created motions using the robot's Web GUI. This is useful if during hands-on training they consider the need to reduce the speed of some motions to ensure greater perceived safety, as it should be considered that older people are slow in movement and weaker [12].

2) Hardware adaptation: Additional components have been added to ARI, namely:

- An additional Android tablet at the back side for greater accessibility, this may be retrieved by end-users so that it is easier to interact with if they are seated
- A thermal camera for temperature monitoring (COVID-19 solution)
- Exchange Head RGB camera with a RGB-D camera, to provide more robust user authentication, as mentioned

[2]http://wiki.ros.org/play_motion_builder

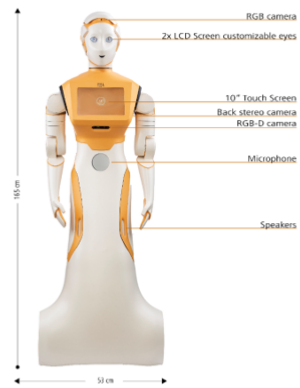

Fig. 3: PAL Robotics ARI robot © PAL Robotics 2021

Fig. 4: Motion Builder to generate new motions © PAL Robotics 2021

in the next section.

The Figure 5 highlights the sensors and components added for the SHAPES-ARI robot together with the original cameras.

Fig. 5: SHAPES-ARI components © PAL Robotics 2021

B. People related interaction

The first group of solutions aims to endow the robot with the ability to perceive and interact with the older people to meet the requirements of the user case: people detection and recognition, fall detection, emotion and user engagement detection, and chatbot for speech interaction.

1) People Detection and Fall Detection: People detection (Figure 6) is one of the basic tasks for robotic navigation, security and interaction. In this case, the digital solution provides additional semantic capacity during navigation by not only detecting obstacles but also recognising them as people. This detection constitutes the main point of the following identification and interaction processes with the people present in the environment.

Additionally, TREE expands the detection of people mentioned above through post-processing that allows its digital solution to detect any falls they may have. This process is carried out through the logical inference of the detection of people in non-vertical positions on the surfaces, as well as, through the detection of events and actions (in this case falls) through neural networks trained by the movement vectors of the scene. This provides robotic systems with an alarm system in the event people fall in their areas of interaction.

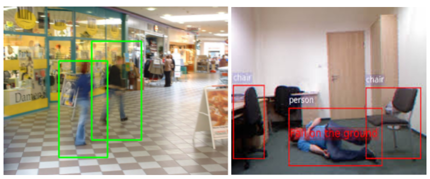

Fig. 6: TREE People detection and fall detection © TREE Technology 2021

2) Emotion recognition and user engagement: Recognition of user engagement is directly related to evaluating user experience, and makes it possible for the robot to adapt its behaviour to the user [13]. Initially, using the cameras embedded in the robot, we determine the different emotional states of the people (detecting up to 8 different emotions: neutral, happy, sad, surprise, fear, disgust, anger, contempt) during the interactions with the robotic system. After this, additional characteristics (eye ratio, gaze direction) are extracted to allow a complex metric of the current user's engagement with the tasks performed in front of the camera to be calculated.

3) Chatbots: Due to their naturalness and ease of use, interest in voice assistants in socio-sanitary domains has grown in recent years [23]. As depicted in Figure 7, these voice assistants like the one provided by Vicomtech for the SHAPES project usually consist of a pipeline of expert technological modules, where each component has a specific task to perform [24]. The chatbot will be trained so users can have conversation with the robot and give speech commands to trigger the different activities.

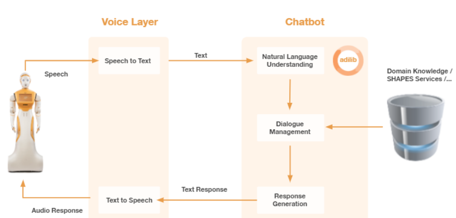

Fig. 7: Text to speech and speech recognition with ARI © VICOMTECH 2021

The chatbot includes the following modules:

- Speech to text: is the module that converts the user audio to text. For SHAPES a DNN-HMM based system is used over the Kaldi recognition system [27].
- Natural Language Understanding: this module uses AI models to convert the raw text into semantically meaningful intents and entities. Open sourced state-of-the-art models and methods are used for this purpose [26].
- Dialogue Manager (DM): this module determines the response to return to the user. The interaction is contextualised according to the task and external information to define the dialogue-strategy to follow. For SHAPES the Attributed Probabilistic Finite State Bi-Automata framework is used for flexible data-driven interactions [25].
- Response Generation: This module transforms the response selected by the DM into a representation adjusted to the end user in terms of the language detected, user experience, channel type and so on.
- Text to Speech: to convert the written response generation into speech, VicomTTS has been deployed. This synthesizer is based on the Tacotron-2 [28] architecture

4) Face Recognition: Vicomtech's FACECOG digital solution is a function from Vicomtech's Viulib library[3], for recognising people's identities based on their facial images, extracted from RGB image files, video files and video-cameras, or from multi-modal RGB and depth images obtained from depth cameras, such as those from Intel's RealSense [22], used by ARI robot. It can be used for video-surveillance applications such as registered people detection at a distance, and for user authentication. It is equipped with anti-spoofing functions based on the analysis of the "liveness" of the facial image detected. Moreover, if multi-modal RGB and depth images are used, the solution provides additional mechanisms so as to avoid spoofing attacks.

No facial images are stored, either during the user registration process, or during the surveillance/authentication process. Only the extracted i-vectors are used, which do not leave the device where the solution has been deployed. The user's facial images cannot be obtained from the extracted i-vectors, as these i-vectors are constructed by learning facial cues from facial image datasets built without any of the final users involved. Thus, the user's privacy is totally preserved. Besides, the i-vectors are cryptographically secured with using a fully homomorphic encryption procedure [21].

C. Technical components for Daily Activities

In order to carry out different activities specified in the requirements to promote healthy ageing, more specific features have been developed. The main ones are highlighted below.

1) Alert system: A voice alert system using Twilio[4] has been developed, which enables contacts to be added, and a voice message delivered to an added contact person. This will be used to alert caregivers in the case of increase in temperature, fall or failure to deliver a reminder.

[3]https://www.viulib.org/
[4]https://www.twilio.com/

2) Temperature monitoring system: Combined with person detection, using the thermal camera, the system measures the temperature of the person once verified that it is inside the silhouette (Figure 8) and triggers alerts if necessary.

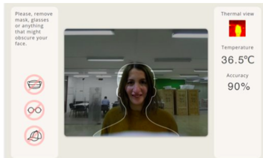

Fig. 8: ARI's temperature monitoring system © PAL Robotics 2021

3) : End users will have the option to initiate a video call through the front touch screen or the back tablet. This will be linked with the robot's API to gain access to its microphone and Head RGB-D camera to stream audio and video, and will interface with the robot's text-to-speech. The specific platform for video calling is still under development.

4) Reminders and follow-ups: Lastly, for the use case presented, there are two main tasks to performed with the chatbot assistant: deliver a reminder through speech (water or medicine intake, cultural activities...); and periodic follow-ups to pre-defined question types (evolution, scoring 1-5, etc) as well as setting up alarms and storage of information for future analysis. Both of these will be inputted by caregivers through a web-interface

D. System integration

Figure 9 indicates a high-level integration of the solutions. Most of the solutions will run locally on the robot, and be connected to the robot either as ROS (Robotics Operating System) nodes or by Rest API: only Adilib for reminders/follow-ups and speech recognition will run externally, as well as the overall SHAPES platform.

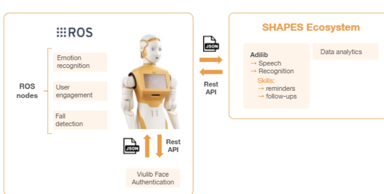

Fig. 9: Software integration on ARI for SHAPES project © PAL Robotics 2021

As there are quite a number of tasks, an example scenario of how some of these solutions integrate with each other can be observed in Figure 2, where each solution is indicated by a red circle.

The goal is for the robot to deliver a reminder to the specified end-user. The input is the user Id, the task to carry out (reminder), type of reminder (e.g. text, "take your pill") and time of reminder. This is provided by Adilib Reminders skill, from the SHAPES platform in the Cloud. The robot will be programmed to move through a set of pre-defined points inside the house. In order to navigate safely inside the house and avoid obstacles [29], it uses a visual navigation system.

Once it reaches the first point, it will call for the person to encourage him or her to come face to face with the robot (People Detection module). The robot will then identify the person using the FaceCog solution or by asking the user to introduce credentials through the touch-screen. Once the user is verified, it will give the reminder or suggestion.

The user will be asked to press the button on the robot's touch-screen to indicate the reception of the reminder. If so indicated by the caregivers, in the event that no response is obtained after a given time, the robot will send them an alert using Twilio. After each interaction, the robot will store interaction data (e.g. type of interaction, user id, time) to be analysed within SHAPES. It will then proceed to ask if the user wants to do something else, using animated speech, and display all the options in the touch screen. If no interaction is desired, it will return to the charging station.

V. VALIDATION PLANS AND ENGAGEMENT ADAPTATION

As a pilot of the SHAPES project, the pilot campaign has been devised by the consortium in collaboration between over 36 partners. It consists of 5 phases that involve testing the solution selected, which is adapted, integrated, deployed and evaluated by end-users, as described more in detail by Spargo et al. [30].

At the time of writing this paper, the first and second phases have been completed, Planning and Design as well as Mock-ups testing, are as described previously.

After the prototype development of the solution, a hands-on training with a double objective is planned starting early July 2021 so that: 1) the users get familiar with the solution in practical sessions, 2) further feedback is collected in terms of usability and user experience from all the end-users identified (older people, caregivers, technical people). In these sessions, the human-robot interaction and robot acceptability will be analysed. After the hands-on training, some tasks will be discarded or improved based on the feedback and usability. Finally, before the pilot (Phase 5), there will be a real-setting test with only 2 older people participating (Phase 4), in October 2021, one living in their own home and the other independently in a sheltered apartment complex. This last test will serve as the final validation of the different functions, where adjustments should be minor. The real pilot is expected to be carried out on 5 participants, 1 living in their own home and 4 in sheltered apartments. Each one will be living with the robot for about 3 weeks.

1) Data Collection plan: The evaluation plan of the pilot will be in accordance with the SHAPES project's main questions, as described in [30]. Specifically for these pilots, interaction data will be stored, such as type of activity, user ID, date, how many days the robot was used, average time of interaction per day, duration of the longest interaction, and rating. The data will first be collected in the robot, using $pal\_statistics$ [5], and then be sent to SHAPES Data Lake for

[5]http://wiki.ros.org/pal_statistics

subsequent data analysis. Some analysis of interest includes evaluating which tasks were most used and how to generate greater engagement, and which robot behaviour resulted in higher interaction with the robot. This is expected to help evaluate robot acceptance among end users. Regardless of the aforementioned, a better definition of data analysis will be provided in upcoming papers.

2) Robot behaviour adaptation plans: Based on the feedback from the hands-on training and user engagement detected, ARI's behaviour will be modified, including, but not limited to: the amount of encouragement of feedback the robot gives during activities, locations where the robot travels to within the house, human-robot proxemics to establish a user-preferred interaction distance or robot position relative to the user, or touch-screen interface design, such as size of buttons. For example, in the case of the scenario where the older adult approaches and plays a game with ARI, if the user engagement module indicates that the user is frustrated, the robot will first provide stronger encouragement, and then suggest switching the game or doing something else.

VI. Conclusions

This paper describes the development of a social robotic application to support active and healthy ageing through the H2020 SHAPES Project's user- centred methodology. User requirements have been collected jointly from the end users at Clínica Humana private clinic and the expertise from the SHAPES consortium, in order to develop and integrate a set of digital solutions from SHAPES onto the robot.

Upcoming papers will describe the validation plan in detail as the first tests are being conducted early July 2021 at the clinic, after which the robot's features will be adapted based on new requirements and feedback. The paper tries to push things in the direction of addressing the missing points for robots in order to be used in real life scenarios and, alongside other technical solutions developed within the SHAPES project, promote independent living.

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