Deliverable 25.9

Evaluation results

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Glossary of Terms

ECHORD++: European Clearing House for Open Robotics Development Plus Plus (E++ for short)

2 User Studies and Usability, Accessibility and Social Acceptance Results

2.1 Introduction

Within CLARC, the fundamental service that the robot provides is the ability to autonomously conduct the tests within the CGA. However, before driving the tests, the CLARC robot needs to introduce itself as an accessible and helpful assistant (or, at least, tool). Elderly people undergoing CGA procedures are usually not at all familiar with robotic technologies. It is crucial for CLARC to make them feel comfortable and reassured, and offer them natural and intuitive ways to interact. The way the robot opens the interaction and engages with the person represents a service in itself (see Figure 1), which has a set of requirements: the robot has to greet the patient, introduce itself, and explain the test to be performed and the available interaction channels (voice, touch-screen, and physical buttons).

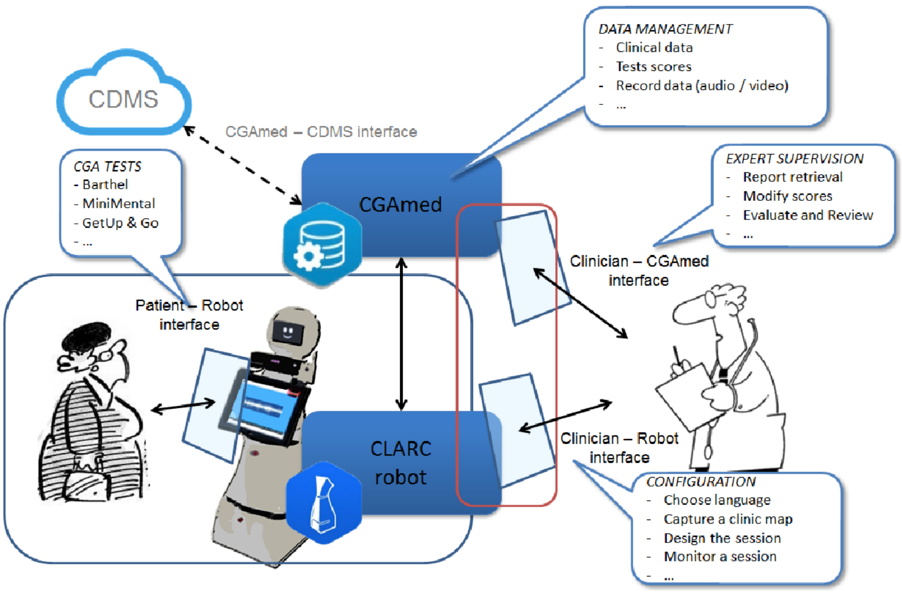


Figure 1. Global overview of the CLARC framework

The main research questions when introducing a robotic solution in such a context like CGA evaluation are the performance of Human-Robot Interaction and social acceptance: “will the solution be accepted by the elderlies?”. These research questions have been examined during Phase 2 and Phase 3: user studies were made using a Participatory and Human-Centred Design approach. The objective was to achieve “appropriate design” of this robotic solution – i.e., a solution that is performant in terms of HRI and that is socially acceptable – based on a proper understanding of: (i) needs (elderly users’) and (ii) practices (work practices specific to institutions, e.g., hospitals and CGA). The user studies made have been coherently led as part of an Iterative design process.

This deliverable describes the approach used, the iterative design process, including how the robot was successfully improved at each step the objectives, and the scientific contribution in Human-Robot Interaction.

2.2 Approach: human-centred and participatory

With the pragmatic objective of achieving “appropriate design” of Clara, the CLARC consortium has led the user studies, adopting a Human-centred and Participatory Design Approach (see Figure 2), putting the end-user at the centre of all design considerations, and involving the stakeholders all through the research process.

2.2.1 Human-centred Design

Human-centred interaction design would be HCI “centered on the exploration of new forms of living in and through technologies that give primacy to human actors, their values and their activities” [Bannon, 2011a]. It takes as a starting point human (elderly) capabilities, with a focus on how to support, develop and extend people’s capabilities through the latest technological developments [Bannon, 2011b]. A radically reworked agenda is therefore proposed, for example, on the theme of Ambient Assisted Living. Instead of a technology-first or even medical-first approach, it is recommended to consider first the fundamental needs and concerns of the ones at the centre of the investigations – the elderly people – so that these AAL technologies could, not only be life-saving, but actually add to elderly people’s dignity or empowerment.

In order to consider elderlies’ needs, different methods have been used: user tests, Ethnography of CGA practices, Interviews, focus groups. Ethnography, especially, offers the opportunity to reveal needs or practices of users which they may not themselves attend to, because they take them so much for granted that they do not think about them, or are too busy [Randall & al, 2017]. This inability to articulate “needs” is even more true of dependent elderlies, especially those suffering from cognitive impairment.

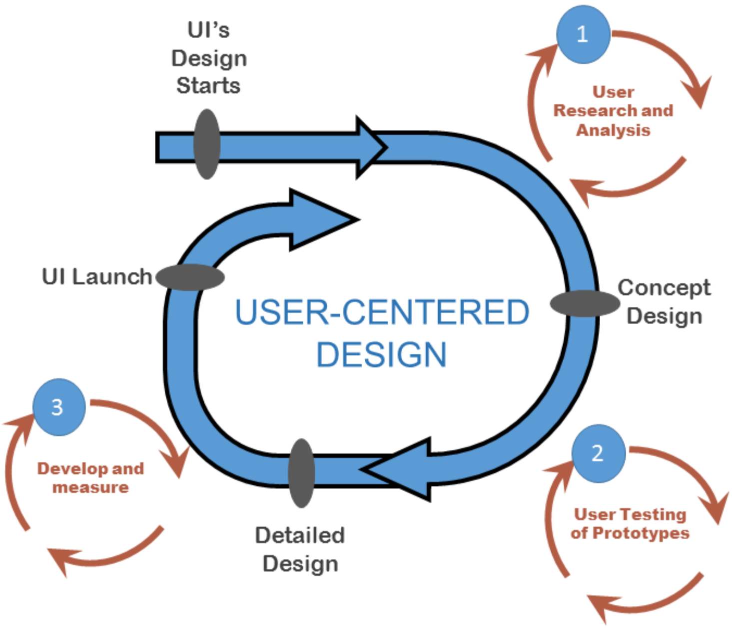


Figure 2. User-centered and Iterative Methodology in CLARC (Lan Hing Ting & al., 2018)

2.2.2 Participatory design

Participatory design (PD) is a cooperative design process, with a focus on enabling different stakeholders with different perspectives and competencies to cooperate. It comprises active user involvement and participation in the design of IT artefacts and systems in professional settings, where it is largely and increasingly used. Designers invite future users to participate in all phases of the design process [Bratteteig & Wagner, 2016]. PD is generally united by an ethos of empowerment and 'meaningful' involvement for stakeholders in the design of the systems they will use.

Participatory design has traditionally been useful in the design of technology applications or the co-realisation of a more holistic socio-technical bricolage of new and existing technologies and practices. Moving away from the traditional computer and "user" notion, e.g. with Ambient Assisted Living technologies or social robots, there is indeed the need for participatory design.

Indeed, research in PD focuses both on the conditions for user participation in the design and on the introduction of computer-based systems at work (Kensing & Blomberg, 1998). This is partly politically motivated, i.e. in terms of social democracy, and partly pragmatically determined: it is believed that systems stand more chance of success when those who will use them have been able to have a stake in their development (Martin et al., 2008). The participation of the intended users in technology design is seen as one of the preconditions for good design. Making room for the skills, experiences, and interests of workers in system design (or end-users in robotic solutions' design) is thought to increase the likelihood that the systems will be useful and well integrated into the work practices of the organization (Kensing & Blomberg, 1998).

2.2.3 Central value: empowerment

Based on the principles of Human-centred Design and Participatory Design[1], the results from the different iterative evaluation (described in section XX below) have shown that CLARC project's actions has succeeded in both achieving "appropriate design" – in terms of social acceptance, usability and accessibility – but also in empowering older adults.

Indeed, empowerment has been researched both from the pragmatic and the political perspectives. We believe that the two dimensions are closely linked, which can be illustrated through 3 aspects.

Term used

In the very terms this research has been using to refer to geriatric patients, the term "participants" has been preferred to "users" and even more so to "beneficiaries", illustrating the principle of Participatory Design which researches *with* (and not *for*) participants, who play an active role as experts of their own experience

Accessibility

The objective of empowerment is also researched in terms of how we integrated accessibility in the HRI Design and the evaluation criteria (see AUSUS framework in Contribution section supra). Including Accessibility as a new performance indicator in HRI evaluation, CLARC project made sure everyone can interact with Clara. First, by proposing different modes of interaction that could answer different needs / preferences. And in proposing multimodal interaction, we focused positively on *abilities*: on what people can do and that can be supported by technology, rather than negatively on *dis*-abilities that would require special support or correction.

"Empowering" elderly patients

One main and interesting insight is how a robotic solution for CGA allows to avoid the pitfall patients' feeling of judgement on the part of health professionals. Indeed, the Barthel test can be difficult for patients, who are asked about continence. Answering a robot, some of them say, avoids the feeling of "the doctor being judgy", therefore allowing for more valid answers, or at least to empowerment of elderly patients. This perception is shared by patients across the 2 countries.

Spanish older adult, Seville Dec 2018, when asked in the post-test interview how he feels after having done the test with the robot at the primary care centre:

"*Very well, I'm very happy to do it. I preferred the robot to a doctor both to talk about personal issues and to feel better after doing the tests."*

[1] The combination of which, we have termed elsewhere as being the « Living Lab approach » (Lan Hing Ting & al., 2018)

French older adult, Troyes, January 2017, during the interview after the user test at the Living Lab:

"*You don't feel that the person is upset... sometimes it can happen, right? it's true that with people sometimes, they're in a hurry in terms of time. But not now, no. It's true that in the end the robot doesn't tell you "go faster"... finally it's not that bad*"

2.3 Iterative design approach

The iterative design approach mobilized the appropriate methods that were coherent with the development phase, and has allowed to improve the Clara robot at different successive stages. Figure 3 summarizes the different actions and timing of this research.

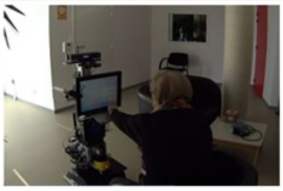
Prototype V1	Prototype V2	Prototype V3	Prototype Jan 2019
			
Jan 2017 (Fr.) - User tests - Focus group - Interviews (Needs analysis)	**March 2017 (Es.)** - User tests - Co-design **May 2017 (Fr.)** - Co-design	**Sep 2017 (Es.)** - User tests	**Dec 2018 (Es.)** - Pilot studies → **Efficient tool** : - Socially acceptable - Efficient HRI

Figure 3. Iterative Design. Actions and timing

2.3.1 Preliminary user tests

Based on a first working prototype (the casing, which was waiting to be co-designed was not even present then – see extreme left picture), we made user tests as part of a need's analysis.

Indeed, testing with real users is the most fundamental usability method and is in some sense irreplaceable, since it provides direct information about people's use of the system and identifies precisely the problems with the interface being tested [Nielsen, 1994]. These user tests were video recorded, to capture in detail what users actually do – on and beyond the screen – but also the outputs produced by the system. Also, the tests were immediately followed by debriefing interviews to collect users' feedback and suggestions.

Figure 4. CLARC robot driving the Barthel test

The user tests focused mainly on the 3 tests implemented in the robot.

1) Barthel test

Functional status is measured by activities of daily living (ADL) through the Barthel's Index Rating Scale [Mahoney & Bathel, 1965]. It is based on ten questions, evaluated following a Likert scale structure. It usually lasts about 5-15 minutes. The test can be filled in by the patient, or a relative/caregiver, and it can be related to present or past conditions. The robot was then able to ask questions using 2 natural interaction channels (i.e.voice output and text on screen). For each question, two, three or four possible answers are offered. The person can answer questions either by speaking or touching the appropriate option on the screen. Both channels were submitted to end-users' appreciation.

2) Mini-Mental State Examination

MMSE is one common tool used in cognitive function assessment [Folstein & al., 1965]. MMSE also takes 5-15 minutes and examines functions including orientation, immediate and short-term memory, attention, calculation, recall, language, and ability to follow simple commands. It is used for screening for cognitive impairment, and also for follow-up of cognitive changes in patients suffering from dementia. CLARC collects answers using voice recognition, the touch screen, and a tablet device that is offered to the patient to answer certain questions (e.g. those related to drawing).

3) Get Up & Go test

Get Up & Go test [Mathias & al., 1986] requires the patient to stand up from a chair, walk a short distance, turn around, return, and sit down again. The goal is to measure balance and fall risk assessment, detecting deviations from a confident, normal performance. CLARC has to give instructions to the patient, position itself in a proper location to observe the complete motion, and provide a signal to start the test. For successful automation of the test, the robot needs to perceive the gait and to analyze balance and timing issues. Tests include closed-answer questions (”select option 1, 2 or 3”), open-answer questions (”What day is today?”) and monitoring of simple (”close your eyes”) or complex (”get up from the chair and walk three meters”) patient movements.

CLARC is intended to work with real patients in real-life hospital environments, thus it needs to be much more than a simple survey tool. The hypothesis driving the design of the first prototype, confirmed by the results of the user studies, is that CLARC's Automated Planning abilities allow the planning of the interaction with the user and to adapt to exogenous events, like the patient not answering a question, asking for help or leaving the room. During the tests, CLARC collects, saves and displays the responses.

2.3.2 User tests: results and insights

The user needs collected led to valuable design decisions to improve both interface and interaction. All the users finished the tests, including a 93 year old lady who was helped by her daughter. The average duration time for each test is Barthel: 13'48 min, Get up and Go: 2'27 min MMSE: 26'37 min. The users were generally satisfied with the Barthel test. Three users (aged 87, 93 and 93) visibly had difficulties understanding the interaction with the screen, and seemed to answer haphazardly, therefore invalidating the results if it had been a real Barthel test. All the users found the explanations for the Get up and Go presented by the robot difficult to understand, because it was too long, asking the user to perform different tasks, and the explanation was not accompanied by video images or the like. Two users out of three declared being satisfied with the MMSE.

The user tests provided us with valuable information to consider in order to improve the system interfaces. First, the deep analysis and study of the users' needs thorough guidelines, recommendations, heuristics and standards, provided the CLARC' developers with essential information to take into account during the user interfaces' design. Then, during the user studies conducted with the stakeholders, we obtained new user-requirements which helped us to adjust the interfaces to the user's real needs. This has led to more development work on new version of the interface and implementing new functions, taking into account the insights gained from the user studies, which have been translated into design decisions.

2.3.3 Interviews and focus groups

The objective of interviews and focus groups was to capture user requirements, by understanding patients' expectations about medical consultations, geriatricians' practices and preoccupations, and what people mutually value in the interaction between nurses/caregivers and patients. This way, we could examine the envisaged added value of the robot and look into its acceptability for both end-users' profiles.

Together with the user tests, valuable feedback was gathered to improve i) the usefulness of the functions, ii) the usability of the Graphical User Interface and iii) the interaction with the multimodal framework - speech input and output, and touch.

2.3.4 User tests – second iteration

Two months later (Prototype V2 in Table of Fig 2 infra), based on the insights of the preliminary user tests, a second version of CLARC robot has been redesigned, that is more user-friendly, helpful and useful. At that stage, the objective was to check the accessibility and usability of the new version of the CLARC prototype, while broadening the scope to the appropriation and assimilation of this robotics tool. The tests were made in a residence home in Seville, i.e. with participants who were less active than the ones who came to the Living Lab at Troyes, France.

2.3.5 Accessibility

These user tests allowed the observation that users were having when interacting with CLARC despite all the usability improvements that had been made. The problem was therefore not usability, but the extent to which most of elderly patients had sensory impairments (visual and hearing) as well as cognitive impairments, due mainly to the age usual degeneration, which prevented them from interacting efficiently with Clara (or any other technology). The design was improved (from (b) to (c) in Fig. 5), including visual cues, like colours and forms, that would correspond to the physical remote control's forms that was also proposed at that stage (see technical deliverable for details) and the evolution of the remote control design taking into account accessibility in Figure 6.

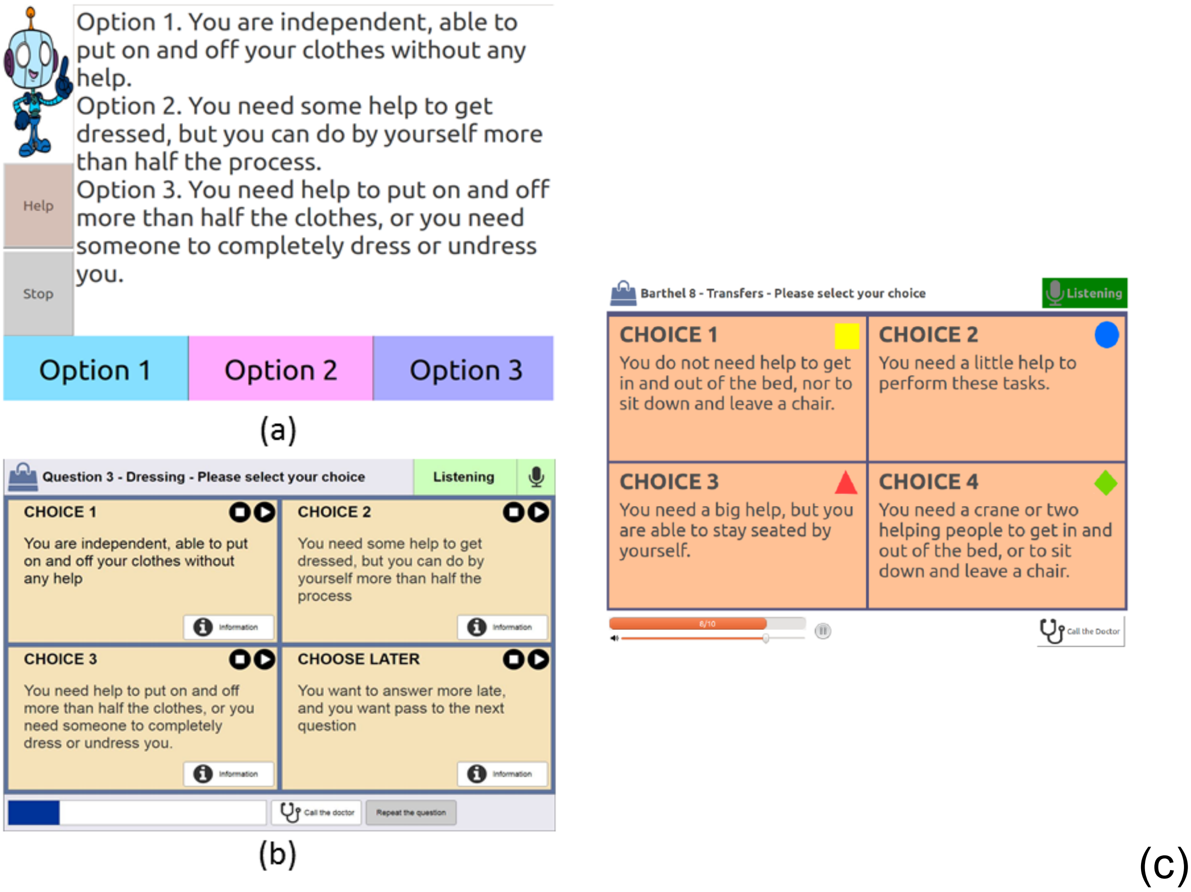


Figure 5. (a) First (b) Second, and (c) Final interface of the Barthel test, following iterative improvements

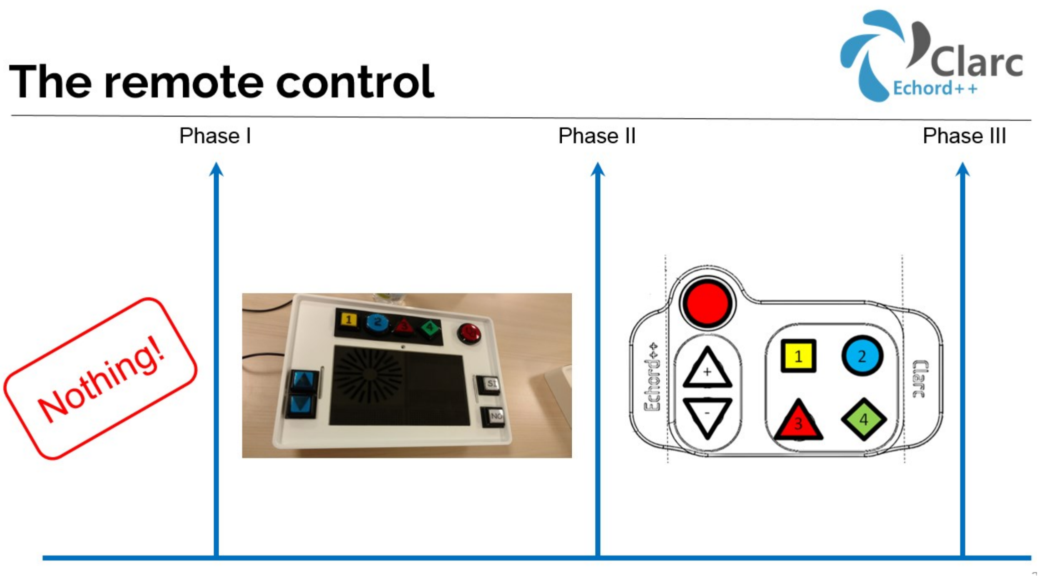


Figure 6: Evolution in remote control design idea

A deep analysis of the accessibility barriers has been carried out by an accessibility expert, then an accessible design of Clara was proposed, including multimodal interaction: the patients could choose in any moment the mode of interaction with the robot: by voice, touch screen, written text - captioning-, physical buttons in a remote control, among others. In this way, Clara was adapted to interact with the patients in an inclusive way, nevertheless of the patients' characteristics, abilities/disabilities, needs and preferences, facilitating the interaction. This contributed, as explained above, to the empowerment of patients, which emerged as a secondary objective to attain in the project.

Therefore, related to the evaluation framework, another contribution of the CLARC consortium is the AUSUS framework. It complements the existing USUS framework, which is the complete framework for HRI evaluation, examining Usability, Social Acceptance, User Experience, Societal Impact. Accessibility was therefore a 5th criteria added. The AUSUS framework, designed as part of CLARC research, was used as the evaluation criteria of the pilots.

2.3.6 Co-designing CLARC's looks

Another important issue, in order to attain the social acceptance criteria, was the necessary involvement of stakeholders in the co-design of the casing, so that the robot's appearance would correspond to users' needs. The physical aspect that was co-designed, in both Spain and Troyes, was coherent with stakeholders' perception of the robot as a geriatric assistant. The chosen colour: white, looks: neutral, so that Clara looks sobre and can be cleaned easily.

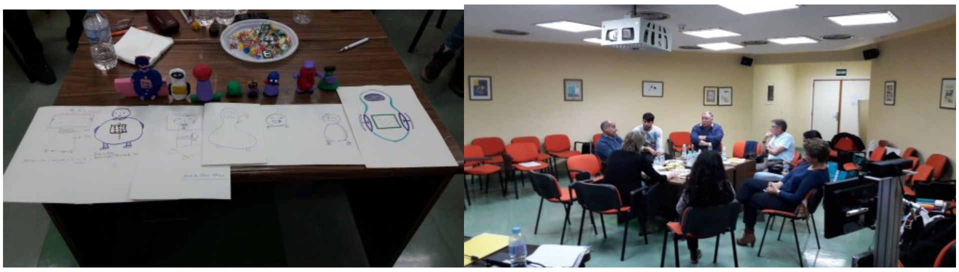


Figure 7: Co-design session in Seville, March 2017

The choices were made about the physical appearance, but also about important functions. Indeed, linking the use case scenario to the appearance during the reflexion, participants raised the question of what would happen of a patient wanted to call for help after a fall. Lying on the ground, a fragile patient would not be capable of pressing the button in the middle of the robot.
Therefore, a second button has been implemented in the final design (see Figure 8).

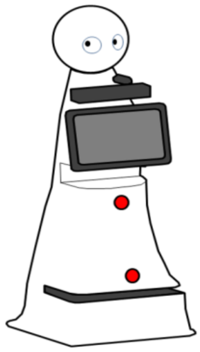


Figure 8: Two buttons (lower button in the case of a lying position)

Figure 9: Co-design session in Troyes, May 2017

The two co-design sessions included both a comparative dimension and an iterative process, so that the second session refined the design ideas of the first. The second co-design session in Troyes included drawing and molding one's own robot and collectively discussing its looks (like in Seville), but also a live videoconference co-design session with an engineer from MetraLabs. What has been particularly appreciated (and impressive) from the participants' perspective was to have access to a high-tech robotics software design tool, and to see in real-time the suggestions being heard, considered and implemented.

2.3.7 User tests – third iteration

Eight patients from the retirement home participated in the study, interacting with CLARC robot to complete the Barthel test of the CGA evaluation process, related to the functional capabilities of elderly persons. Figure 10 describes the main characteristics of the patients who participated in the evaluation who had a mean age of 81.37±12.07 years. There were seven women (87.5%) and one man (12.5%).

User ID	Gender	Age	Motor Impairments	Hearing Imp.	Visual Imp.	Cognitive Imp.	New technologies skills
user1	Woman	86	In a wheelchair from a recent hip fracture	no	no	no	Mobile phone and tablet (phone calls and photos).
user2	Woman	75	Uses a walker to move around due to senile impairment	light	no	no	Mobile phone (phone calls and photos) and computer (Internet navigation)
user3	Woman	84	Uses a walker to move around due to senile impairment	light	medium	light due to the age	Mobile phone (phone calls and photos)
user4	Woman	55	In a wheelchair due to lower limb impairments	no	light	light	Mobile phone and tablet. Advanced user (continuously).
user5	Man	93	Light impairments related to age	medium	light	no	Mobile phone (phone calls and photos)
user6	Woman	84	Uses a walking stick to move around due to senile impairment	no	light	light	Mobile phone (phone calls and photos) and computer (Internet navigation)
user7	Woman	82	Light walking impairments but without technical assistance	no	no	no	Mobile phone (phone calls and photos) and computer (Internet navigation)
user8	Woman	92	Uses a walking stick to move around due to senile impairment	light	no	no	Mobile phone (phone calls and photos)

Figure 10: User's characteristics at the Retirement Home Evaluation

Quantitative and qualitative methods were complementary combined to answer the research questions, examining both the patients' and the clinicians' perspectives:

- Test and structured interviews: user tests and interviews were done with the patients in the retirement home, and simple tests and a structured interview to the clinicians who participated in the observations with the CLARC robot collected clinicians' point of view and requirements. Interviews were used before and after the test. Before users interacted with the robot, sociodemographic variables and new technologies use and skills (mobile and computer skills among others) were surveyed. After the interaction with the robot, questionnaires and structured interviews were conducted to measure subjective usability criteria and future intention to use the robot. The test, questionnaire and structured interviews contained questions on a Five-point Likert scale (2) (from 1 = do not agree to 5 = do fully agree), examining users' perception of usability, social acceptance, user experience and impact of the CLARC robot (see details on the description of USUS framework at the section).
- Objective data: During the user tests, the robot recorded objective usablity criteria about the interaction, in terms of success in achieving the planned tasks: percentages, mean average time per test / question, standard deviation, total number of answered questions, etc. Also, as a useful assistant performing the evaluation autonomously, the robot also saves the score for each answered question. These quantitative data are complemented with knowledge about how the tests are actually achieved. E.g: Log analysis reveals that user2 failed in answering questions 1 and 3.
- Observations: observation of the interaction with the robot during the test (in situ or videotaped) allows an identification of the exact difficulty: interaction

with the interface, hearing problems, not knowing what option to answer, Automatic Speech Recognition (ASR) or touchscreen not considering the answer given by the user, etc.

- Heuristic Evaluation: accessibility evaluation of the robot interface made by experts according to accessibility guidelines, recommendations and standards.

The 8 elderly users interacted with the CLARC robot to perform the Barthel test one after each other, and were interviewed by the researchers before and after the interaction with the robot, as explained in Section . Each test with the robot lasted about 30 minutes.

Then, the system usability, social acceptance, user experience, societal impact and accessibility was assessed using the AUSUS evaluation framework, which main factors and methods are summarized in Figure 11

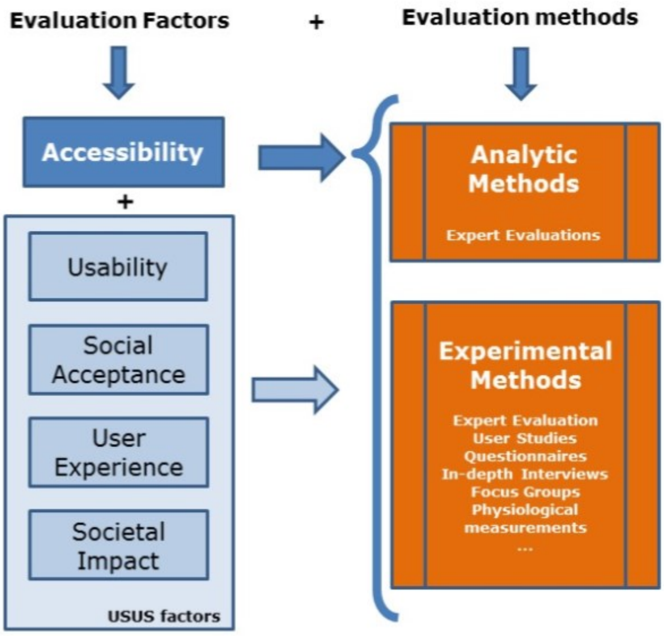


Figure 11. AUSUS framework evaluation factors and methods.

Usability

The performance indicators below have been taken into account to assess the system's usability:

- Effectiveness: CLARC robot is effective if the robot is able to successfully ask the Barthel test questions to the patients, processing properly their answers and providing a adequate evaluation and recommendation to the doctor. Therefore, objective data related to the number of successful questions answered by the users were evaluated to asses this performance indicator. Moreover, one clinician supervised evaluation and recommendation given by the robot after the Barthel test for each user. Finally a clinician completed the Barthel test with the same users a few days after the interaction with the robot, in order to compare the results of CLARC robot and the results obtained by the clinician.

- Efficiency: a comparison between the time spent by the robot to complete a Barthel test and the time spent by a clinician is done. The robot is efficient if the users do not spend more time interacting with the robot than necessary.
- Learnability: to evaluate this indicator, firstly, the users were asked about their skills related to the use of new technologies (smart phones, computers, tablets, robots, etc.) and if they were familiar with this kind of robots and/or the Barthel test before the interaction. Secondly, the interaction sessions were observed by a clinician and an engineer. Finally, after the interaction session and through a structured interview (questions q1--q4 at Figure 12), the subjective opinion of the patients related to the system's learnability was surveyed in a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). Finally, correlations were studied. As it can be seen in the table, the mean of this question was of 4.14 and the standard deviation of 1.21. The tables included in this paper indicate the values obtained in the evaluation of CLARC robot, mean and standard deviation. However, due to the main aim is not the evaluation of CLARC robot, but a case study of applying AUSUS, these values are not commented in the rest of the paper.
- Flexibility: the different ways the patients can use to communicate with the system are evaluated. CLARC robot provides the patients sevveral ways to interact with it: voice, a touchscreen tablet and a remote control with physical buttons. Therefore, each patient could choose the interaction modality that better corresponds to his/her abilities and capabilities. Firstly, an expert evaluation was carried out to evaluate the multi-modality of the system. Secondly, observations were done to check which one were preferred by the users. Finally, question 5 in the structured interview revealed if they found the robot to be flexible.
- Robustness: to evaluate if CLARC is able to correct and prevent novel user's errors. Firstly observations of the interaction sessions were analyzed. Secondly, the number and type of errors in each interaction session was stored and analyzed objectively taking into account the functional diversity of the patients. Finally, the patients were asked about their subjective opinion after the interaction through a open-question (question 6).
- Utility: to asses this indicator and taking into account the results of the effectiveness indicator, the patients were asked if they think the robot is useful for CGA assessments (question 7 in the structured interview questionnaire).

Question ID	Description	Mean	SD
q1	I could hear and understand the robot clearly	4.14	1.21
q2	Learning to operate the robot was easy for me	4.28	1.11
q3	I found the robot easy to use	5.0	0.0
q4	The robots explanations of what I had to do were clear and understandable	5.0	0.0
q5	The robot is flexible for me to interact with	4.57	1.13
q6	I found errors during the interaction	2	1’57
q7	I think the robot is useful for CGA assessments	4.71	0.48

Figure 12. Patient’s structured interview dealing with usability

Social Acceptance

To study CLARC robot is accepted by patients and clinicians, the *performance expectancy* and *effort expectancy* indicators were not evaluated, because the patients had no idea about the functionality of the robot until it was introduced during the interaction session. In the same way, the indicator related to *forms of grouping* is not evaluated because the interaction should be individual for the Barthel Test in the CGA assessment. Finally, the *attachment* was not assessed because users could not interact with the system enough time to evaluate this indicator.

The evaluation process for the rest of the indicators is explained next:

- Attitude towards using technology: Firstly, the patients were asked about their interest in technology before interacting with CLARC robot. Secondly, the interaction sessions were observed by clinicians and engineers to check their motivation and concentration during the interaction. Finally, the patients were asked four questions during the structured interview (questions q8-11) in Figure 13.
- Self Efficacy: to evaluate this indicator, patients were asked after the interaction with CLARC robot if they felt self-confident doing the Barthel test with the robot (question 12 - q12 - in the structured interview).
- Reciprocity: this indicator was evaluated through a question in the structured interview. Question 13 -q13- asked to the patient asking to the patient if they had the impression of "really interacting" with the robot.

Question ID	Description	Mean	SD
q8	I was motivated and concentrated during the test with the robot	4.71	0.48
q9	I feel comfortable doing the test with the Robot	4.85	0.37
q10	I would like to use a robot similar to CLARC next time for CGA assessments	4.57	1.13
q11	It is easier for me to focus when I am doing the CGA assessment with a robot than when I do it with a human person (doctor, nurse, etc.)	2.43	0.97
q12	I feel self-confident doing the Barthel test with the robot	4.85	0.37
q13	I had the impression of ”really interacting” with the robot, not just answering to a machine	4.85	0.37

Figure 13. Patient’s structured interview dealing with social acceptance

User Experience (UX)

To study if patients and clinicians have good experiences interacting with CLARC robot, the next indicators are assessed through session observations and structured interview analysis:

- Embodiment: both observations and structured interview analysis (questions q14-q17 in Figure 14) were carried out to assess the relationship between the robot and its environment.
- Emotion: questions q18-q21 asked to the patients to check their emotion interacting with the robot.

- Human-Oriented Perception: questions q22-q25 assessed this indicator in order to check if the patients perceived a human-oriented interaction.
- Feeling of Security: the users were asked if they felt physically secure and confident during the interaction (q26-q28).

The only indicator that is not evaluated in this study is the co-experience with robots, because it is related to how individuals develop their personal experience based on social interaction with others.

Question ID	Description	Mean	SD
q14	I felt impressed when I first saw the robot's appearance	1	0
q15	I felt comfortable doing the test with the Robot	4.85	0.37
q16	I felt at ease being in the presence of the robot, whose physical aspect was not impressive	5	0
q17	The robot was engaging and made me feel at ease interacting with it	4.43	0.53
q18	I hesitate to use the robot, because I am afraid of making mistakes	1	0
q19	I was afraid of not knowing how to do the test with the robot, or breaking something	1	0
q20	From my experience of CGA, I think it is easier to talk of difficult subjects with a robot than a health professional	2.14	1.06
q21	I feel better now than before interacting with CLARC robot	3.28	0.75
q22	I had the impression that my oral answers were well taken into account	2.5	1.49
q23	It is easy to answer using the tactile screen or remote control when the robot does not hear	5	0
q24	I had the feeling that it was natural when speaking with, using the touch screen or the remote control of the robot	4.85	0,37
q25	In the way the robot talks, I consider it as being polite enough	5	0
q26	I feel physically secure with the robot, whose behaviour and movement is predictable	5	0
q27	I feel confident during the interaction with the robot which is social	4.86	0.37
q28	I believe the robot is actually and efficiently collecting the data for the doctor to use 4.71	0.75	

Figure 14. Patient's structured interview dealing with User's Experience

Societal Impact

The societal impact of CLARC robot is evaluated through *quality of life*, *working conditions* and *employment indicators*. *Education* and *cultural context* are not assessed in this study, because these indicators were out of the main aims of the study (see Figure 15}.

- Quality of Life, Health and Security: to check if CLARC could be integrated into the everyday life, both observations and a question in the structured interview analysis were performed. The question was "q29 - I think that if robot does the CGA assessment, the doctor will have more time for human contact".
- Working Conditions and Employment: through a focus group and a structured interview after the interaction sessions, clinicians were asked "q30 - I think that my working conditions and employment could be improved with the CLARC robot in my current state".

Question ID	Description	Mean	SD
q29	I think that if robot does the CGA assessment, the doctor will have more time for human contact	1	0
q30	I think that my working conditions and employment could be improved with the CLARC robot in my current state	4.86	0.37

Figure 15. Patient's structured interview dealing with Societal Impact

Accessibility

The extension done to the USUS framework is the evaluation of the accessibility of CLARC robot's interface, necessary when the users present functional diversity. Together with the literature review, the insights of previous iterative evaluations of CLARC concerning the specific characteristics of elderly users, had confirmed the necessity to include accessibility factor. This is the reason why this evaluation grid enriches the first four performance indicators of USUS framework, with accessibility as a fifth one, resulting in the proposal of AUSUS framework. The proposed AUSUS framework was used during this evaluation, as follows.

First, a heuristic evaluation was performed by an accessibility expert, taking into account specific recommendations based on accessibility guidelines for HRI such as [Qbilat et al., 2018a] [Qbilat et al., 2018b], general and recommendations based on Accessibility guidelines in HCI such as [W3C, 2008] [FunkaNu, 2014] [BBC, 2014] [TSUI, 2015] and standards as European or International regulations, such as ISO 9241-171, 2008 or ISO/IEC 13066-1, 2011 dealing with accessible interfaces, among others. Automatic tools were used by the experts to help them to evaluate the accessibility heuristics of the robot's display program, such us *Contrast Checker* tool[2], which checks the compliance with the heuristics related to the contrast levels, brightness and shine in the color combination of foreground and background of textual content based on the requirements of the W3C content guidelines [W3C, 2018], or the *Readability Grader1.0*[3] which is a tool that allows people to check whether their content is easy-to-read.

Second, during the interaction sessions in the user studies, observations were done to detect accessibility problems and objective data was stored if an accessibility error occurred during the interaction.

Some of the most problematic accessibility barriers (with a higher priority level) detected during the heuristic evaluation and the user studies were:

- Captioning: some parts of the robot's speech was not captioned, so patients with hearing disabilities couldn't notice the robot's requirements. As recommendation to the designers,

[2] http://contrastchecker.com/. Last access at September 2018
[3] https://jellymetrics.com/readability-grader/. Last access at September 2018

- Robot's voice: the robot's voice was not clear enough, because there was an echo of the sound due to the robot's case. It was recommended to open new sound exits in certain parts of the robot's case.
- Similarity between the interface shown on the screen and the remote control: users with cognitive disabilities usually have problems to make the correspondence between two different devices. In CLARC robot the buttons look on the display were different to the buttons look on the remote control, so the correspondence was not easy to be made for the patients. As recommendations to the designers: similar colors and shapes of the button for both devices; and to light the option buttons to be pressed in each moment in the control device (those which are shown at the display at that moment). That will help the patients to make the correspondence between both devices.
- A button to pause the interaction in the remote control was needed. On the display this button was available at every moment.

All this accessibility barriers are now been solved by the designers.

The insights gained from both the expert analysis and the observational analysis confirm the usefulness of considering accessibility in our use case of HRI for elderly users. This factor, as included in the proposed AUSUS framework will be further investigated in the next step of this research. While the use case presented in this paper has allowed to validate the proposed framework, the methodological usefulness of AUSUS will be further investigated during the field trials, where the robot will be used in real-life situations, allowing the investigations of issues like long-term use and habituation.

3 Pilot Results

3.1 Dates and centers

The pilot took place between 23 December 2018 and 18 January 2019. It was carried out in two different clinical scenarios:

+ In a primary health center located in Viso del Alcor (Seville) and belonging to the Andalusian Regional Government (Public Health System).
+ In a retirement home called San Nicolás, located in Cantillana (Seville) and belonging to the Andalusian Regional Government (Public Health System).

3.2 Design of the study

3.2.1 Ethics Committee

The study design was approved by both ECHORD and the internal ethics committee of our public health service, and a collaboration agreement was signed with the two centres that participated in the pilot.

All patients who participated in the study signed the informed consent and information sheet giving their willingness to participate in the study and allowing the recording and taking of images.

Rooms

The study was designed and took place in two large, spacious and well-illuminated rooms where the patient was positioned in front of the robot for the Barthel test and therefore the robot has enough space to move and evaluate the Get up and go test.

In addition, an external camera was placed behind the patient and to his right (approximately 45º) to record the tests that the patient performed with the robot.

We would like to point out that the robot that performed the pilot in the retirement home also had available another front camera attached to the robot's kinect that collected the frontal situation of patients.

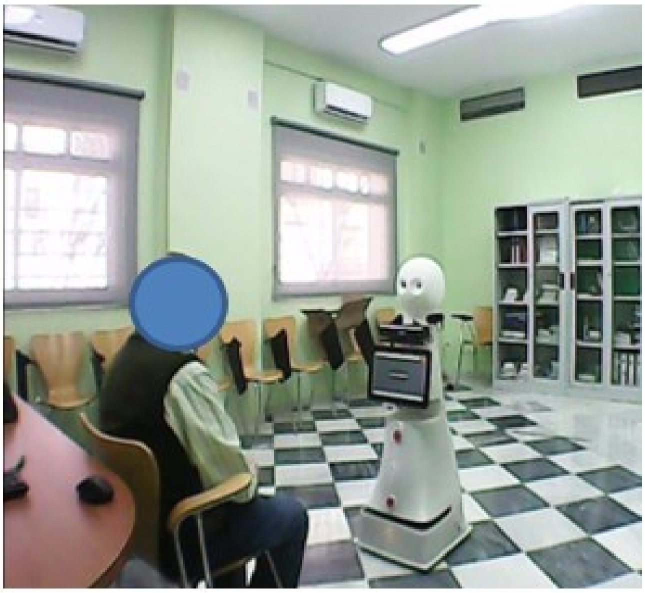


Figure 1: Primary health center pilot room

Figure 2: Retirement home pilot room

3.2.2 Inclusion and exclusion criteria

Inclusion

+ Present ability to collaborate with the study.
+ Give written consent for inclusion in the study.
+ Over 65 years of age.

Exclusion

+ History of psychiatric illness that makes collaboration in the study impossible.
+ No written informed consent to participate in the study.
+ Minimental test less than 23 points.
+ Severe hearing and visual impairment.

*Patients in wheelchairs or with severe motor impairments were rejected for the get up and go test but participated in the pilot through the Barthel's test.

3.2.3 Pilot protocol

Informed consent

When, the patient went to the room where the pilot was carried out, it was explained again what it consisted of (by the clinician in charge of the project). In the case of the health centre, this is where the inclusion and exclusion criteria are passed.

After that, both centres were ready to explain and sign the informed consent and the information sheet after which the pilot was carried out.

3.2.4 Design of the pilot

The objective, in addition to checking the usability, acceptability and interaction of the robot, was to analyze the reliability of the evaluations carried out by the robot in comparison with those carried out by the clinician responsible for the project. In addition, it was designed to evaluate whether the data collected by the robot was transported from the robot to the interface developed for clinicians.

In order to avoid the bias of a prior knowledge or not of the Barthel and Get up and go tests, it was decided to randomize this factor, evaluating the first patient with the procedure 1 and the next one with procedure 2 and repeat the process with all those evaluated.

+ Procedure 1: The Barthel test was performed by the robot and then passed by the clinician and then the Get up and go test was evaluated by the robot and then it was the clinician who passed it to the patient.

+ Procedure 2: The Barthel test was performed by the clinician and then with the robot and then the Get up and go test was evaluated by the robot and just after it was the clinician who passed it to the patient.

In addition, at the primary health centre, two human/robot interaction questionnaires were carried out, one after passing the inclusion/exclusion criteria and the other after the completion of all the tests described above. These questionnaires included questions of usability, accessibility, social acceptance, user experience and social impact.

3.2.5 Patient-robot interaction

The interaction between the robot and the patient was performed by the voice, the patient's touch screen and the remote control provided by the clinician to the patient before the test.

Before performing Barthel's test, the robot performed some games to teach the patient how to use the system.

Figure 3: Patient in the retirement home performing a training game for Barthel

Before performing the Get up and go test, the robot displayed a video of how the test was done on its screen.

Figure 4: Patient in the retirement home visualizing the video before the Get up and go test

3.2.6 Role of the clinician in charge of the project

In charge of passing the inclusion/exclusion criteria and the human/robot interaction questionnaires (only in the primary health centre), passing the clinical tests in the established random order (form 1 or 2) and completing the patient data on the platform through which the tests are launched and the robot collect the data.

The clinician, previous to the robot test, did not teach or anticipate how the robot would perform the test, but only performed the following actions:

+ Told the patient that he was going to perform a clinical test with a robotic solution.
+ Placed the patient in the chair in front of the robot.
+ Gave to the patient the remote control with and said that he could interact with the robot with it.
+ Inserted the patient's data into the platform and launched the tests so that the robot could begin to perform them.

Therefore, during the tests performed by the robot, the clinician did not interact with the patient unless the system/robot was turned off or the patient pressed the button to call the doctor (the called oz-wizard technique). The patient had to solve the doubts and perform the interaction and test only with the help of the robot.

While the patient was performing the test with the robot, the clinician filled in a table for the Barthel and another one for the Get up and go, several observations about the patient/robot interaction.

Get up and go observations ALL sessions	GET UP AND GO TEST OBSERVATIONS							
Number of evaluated patients	Number of patients that had NOT detected at the start of the session by the robot	Number of patients who DO understand what they have to do during the test	Number of patients who do NOT understand what they have to do during the test	Number of patients that the robot stops seeing during the test	Number of patients in whom the robot DOES NOT end the session	Number of patients in which the robot DOES end the session	Number of patients where the system fails and the robot does not perform the test	Number of patients whose data is dumped into the application
8	3	7	1	3	4	4	1	1
11	2	4	7	1	9	0	0	0

Figure 5: Get up and go test observation table

Barthel comentaries ALL sessions divided by centers	INTERACTION PATIENT-ROBOT								
Number of evaluated patients	Number of patients using the remote control to answer	Number of times the remote control was used TOTAL	Number of patients using the touch screen to answer	Number of times the touch screen is used TOTAL	Number of patients using voice/microph one to answer	Number of times patients have used voice/microphone to answer TOTAL	Number of patients who do not answer a question	Number of questions not answered by patients TOTAL	Number of patients answering before the sound signal (enable to answer)
16	16	149	1	1	0	0	2	10	5
29	23	195	1	10	3	20	11	65	1

*Figure 6: Barthel test observation table *(not pasted the whole)*

3.3 Results

3.3.1 Demographics dates

A total of 45 patients have been evaluated, of which 16 were evaluated at the Viso del Alcor health center while 29 were evaluated at the nursing home.

Of the 45 patients, there were 26 men (57.77%) and 19 women (42.22%) with an average age of 79.67 years and a standard deviation of ± 7.33.

A total of 45 Barthel tests were performed through the clinician and the robot (23 Barthel tests evaluated in procedure 1 and 22 in procedure 2) and 19 Get up and go tests performed through the clinician and the robot (10 in procedure 1 and 9 in the 2).

3.3.2 Excluded patients

A total of 66 were excluded of the pilot: 7 in the primary health centre (10,60%) and 59 in the retirement home (89,39%).

Of the total of the excluded patients, 57 patients were because of a Minimental test less than 23 (86,36%), 6 patients due to they had no time or interest in perform the test with the robot (9,09%) and 3 because of severe hearing or visual problems that made it impossible for them to interact with the robot (4,54%).

Origin of the patients	Number of patients excluded from the pilot	**Reason 1:** Patients with a Minimental lower than 23	**Reason 2:** Patients who do not have time or interest to do the tests with the robot	**Reason 3:** Patients with very severe hearing or visual impairment that makes hearing or vision impossible
Primary health centre	7	2	3	2
Retirement home	59	55	3	1
TOTAL	**66**	**57**	**6**	**3**

Figure 7: Excluded patients results

<u>Conclusions (excluded patients)</u>

At the retirement home, more patients were excluded because most of them had a Minimental passed by the nursing home clinicians, which made us directly know that there were many patients with less than 23 points on the Minimental test. In addition, in the residence the patients had an average age (82.3 years) almost 8 years older than in the health center (74.75 years).

3.3.3 Barthel test

Interaction or way of answering

Of the 45 patients who performed the Barthel test, 41 of them used the remote control to answer any questions (91.66% of the total number of patients). The number of times the remote control was used was 352 times (78.22% of the total number of questions answered*).

Of those 45 patients, only 2 used the touch screen to answer any question (4.44% of all patients). The number of times the touch screen was used was 11 times (2.44% of the total number of questions answered*).

Of all the patients evaluated, 3 of them used voice to answer any question (6.66% of the total number of patients). The number of times the voice was used to answer was 20 times (4.44% of the total number of questions answered*).

Of the 45 patients evaluated, 17 did not answer any questions (37.77% of the total number of patients). The number of times a question was not answered was 80 times (17.77% of the total number of questions answered*).

*For this percentage, the 80 unanswered questions were counted as one more way of answering.

The percentage of the number of responses does not add up to 100% because some patients who tried to use their voice to respond, seeing that the robot did not understand them and used the remote control right afterward.

Barthel comentaries ALL sessions unificate	INTERACTION OR WAY OF ANSWERING							
Number of evaluated patients	Number of patients using the remote control to answer	Number of times the remote control was used TOTAL	Number of patients using the touch screen to answer	Number of times the touch screen is used TOTAL	Number of patients using voice/microphone to answer	Number of times patients have used voice/microphone to answer TOTAL	Number of patients who do not answer a question	Number of questions not answered by patients TOTAL
45	41	352	2	11	3	20	17	80

Figure 8: Barthel interaction or way of answering results

Conclusions (interaction or way of answering)

The patients preferred to use the remote control as the main form of interaction with the robot. Our hypotheses consider various options such as simplicity, not having to be incorporated to touch the touch screen or even that the training guides you more to the use of the remote control as a preferential option to the use of voice.

On the other hand, it should be noted that the patients who used the voice did not get their answers accepted by the robot because they tried to converse with the robot telling it the answer.

Misinteraction of patients

Of the 45 patients evaluated there are 24 who attempted to answer before the sound signal/illumination of buttons that allow to answer (53.33% of the total number of patients). The number of times a patient tried to answer before the sound signal/illumination of buttons that allow to answer was 147 times (32.66% of the total number of questions answer).

Only one patient and one time selected an answer and then realized it wasn't the right one.

MISINTERACTION OF PATIENTS			
Number of patients answering before the sound signal (enable to answer)	Number of times the answer was given before the sound signal (enabling to answer) TOTAL	Number of patients who select an incorrect answer and realize their error immediately afterwards	Number of times that patients who select an incorrect answer and realize their error immediately afterwards TOTAL
24	147	1	1

Figure 9: Barthel misinteraction of patients results

Conclusions (misinteraction of patients)

More than half of the patients during the training do not learn to answer in the time established for this. It is necessary to improve the learning of this during the previous training, since in many times, patients were desperate believing that the robot did not work and, in a few occasions, patients tried to press another button of the remote control.

Understanding problems robot/patient

Of the total number of patients evaluated, 5 of them did not understand any questions (11.11% of the total number of patients). The number of times a patient did not understand any questions was 20 times (4.44% of the total number of questions answer).

Of the 45 patients evaluated, 1 of them despite understanding a question, have doubts about the options (they are not identified with any of them, etc.) (% 2.22 of the total number of patients). The number of times a patient despite understand a question, have doubts about the options was 3 times (0.66% of the total number of questions answer).

11 patients have severe difficulties in reading robot questions (24.44% of the total number of patients). On the other hand, 7 patients had severe problems with what the robot tells (15.55% of the total number of patients).

UNDERSTANDING PROBLEMS ROBOT/PATIENT					
Number of patients who did not understand a question	Number of questions not understood by patients TOTAL	Number of patients who, despite understanding a question, have doubts about the options (not identified with any, etc.)	Number of times, patients who, despite understanding a question, have doubts about the options (not identified with any, etc.) TOTAL	Number of patients who have severe difficulties in reading robot questions	Number of patients who have severe hearing problems with what the robot tells them
5	20	1	3	11	7

Figure 10: Barthel understanding problems robot/patient results

<u>Conclusions (understanding problems robot/patient)</u>

Almost 25% of the patients had great difficulty in reading the questions that the robot showed on its screen: Sometimes because the letter is not very large or because they were displayed for too short time. This meant that sometimes the patient tried so hard to read the text so that they sometimes lost part of the audio and did not know the question or what the options said.

Other understanding problems robot/patient

Of the total number of patients evaluated, 13 of them trying to talk to the clinician during the robot test (28.88% of the total number of patients). The number of occasions where patients tried to talk to the clinician during a question in the robot test was 42 times (9.33% of the total number of questions answer).

Of the 45 patients evaluated, 3 patients tried to have a conversation with the robot (6.66% of the total number of patients). The number of times where patients tried to have a conversation with the robot was 28 times (6.22% of the total number of questions answer).

11 patients did not understand the relationship between the option given to them by the robot and the button that represents that option on the keyboard (24.44% of the total number of patients). The number of times where patients did not understand the relationship between the option given to them by the robot and the button that

represents that option on the keyboard was 85 times (18.88% of the total number of questions answer).

UNDERSTANDING PROBLEMS ROBOT/PATIENT					
Number of patients trying to talk to the clinician during the robot test	Number of occasions/questions in which patients attempt to speak with the clinician during robot test TOTAL	Number of patients trying to have a conversation with the robot	Number of times patients trying to have a conversation with the robot TOTAL	Number of patients who do not understand the relationship between the option given to them by the robot and the button that represents that option on the keyboard.	Number of times patients who do not understand the relationship between the option given to them by the robot and the button that represents that option on the keyboard TOTAL
13	42	3	28	11	85

Figure 11: Barthel other understanding problems robot/patient results

<u>Conclusions (other understanding problems robot/patient)</u>

Many patients (more than 25%), although they were previously informed that the clinician could not help them, looked for them, asked questions or asked for their approval before answering. It would be interesting to do some testing without the clinician in the room to see if problems were being resolved.

Some patients, despite understanding the question, did not understand the relationship between, for example, option 2 chosen and number 2 of the remote control. This was especially true for older patients.

<u>System/robot failures</u>

Of the 45 patients who performed the Barthel test, in 3 of them the robot has not captured a response well answered by the patient and requested the patient to answer again the question (6.66% of the total number of patients). The number of times the robot has not captured a response well answered by the patient and requested the patient to answer again the question was 3 times (0.66% of the total number of questions answer).

In 8 patients, the sound that enable to answer appeared at the wrong time during the session (17.77% of the total number of patients). The number of times the sound that enable to answer appeared at the wrong time during the session was 17 times (3.77% of the total number of questions answer).

Of the total number of patients evaluated, in 2 patients despite programming a training game prior to the Barthel test, this training does not appear (4.44% of the total number of patients). The number of times in where despite programming a training game prior to the Barthel test, this training does not appear was 2 times (0.44% of the total number of questions answer).

Only in 2 patients (4.44% of the total number of patients) and 2 times (0.44% of the total number of questions answer) the system failed during a test and the doctor had to intervene.

SYSTEM/ROBOT FAILURE						
Number of patients in which the robot has not captured a response well answered by the patient and requested the patient to answer again	Number of times, patients in which the robot has not captured a response well answered by the patient and requested the patient to answer again TOTAL	Number of patients in whom the sound that enable to answer appeared at the wrong time during the session	Number of times that appeared the sounds that enable to answer at the wrong time during the session TOTAL	Number of patients in what despite programming a training game prior to the Barthel test, this training does not appear	Number of times that despite programming a training game prior to the Barthel test, this training does not appear.	Number of times the system failed during a test and the doctor had to intervene
3	3	8	17	2	2	2

Figure 12: System/robot failure results

Conclusions (system/robot failure)

Only three responses from patients were not captured well by the robot, which did not record them, but asked the patient to answer again. This shows us that if the patient answers properly, the robot is reliable and effective in extrapolating to the interface the question that the patient has selected.

Although it is true that sometimes the robot has not captured the person at the beginning of a test, once the test was started only twice the system failed during a clinical test, which was resolved by turning off the system and restarting it again.

Get up ang go test

	Total	Primary Health Center	Retirement Home
Patients evaluated	19	8	11
Correct Test	1	1	0
Score unavailable	3	3	0
Not registered	15	4	11

Figure 12: Patient's evaluations with Get up and g test.

In the figure 12 the delevelop of Get up and go is included. A total of 19 patients were evaluated, 8 of them in the primary health center and 11 in the retirement home. Before the robot made the evaluations, 1 of them was completely finished and scored. As the figure shows, the score was unavailable in 3 of them and not registered in 15 patients. Score unavailable means that the test has correctly finished but the robot has not scored because he wasn't not sure giving the final score. That happens when, in instead, the Kinect camera has lost temporarily the patients, so his has not followed the movement all the session. In the same way, if the robot has not detected the finish of the session, he not provides scores.

In order to achieve correctly the Get up and go test with the robotic platform is necessary that patients respect every step required by him. His detection system and Kinect camera needs that the patient at the beginning of the test starts stand up near to the chair. If he doesn't respect that, the detection fails. It's why, there are some wrong scores. Figure 13 shows that.

There are tests where the robot concludes the session (4 of 19 sessions), but sometimes some difficulties happen (13 of 19 times in our experience). The reasons could be a natural light source directly in the Kinect camera, chair with armrest., etc. This experience and pilot has shown us certains limitation that will be more controlated in next opportunities to administrate get up and go test.

	TOTAL	**Primary Health Center**	**Retirement Home**
Patients who respect all the steps	11	7	4
Patients who don't respect all the steps	8	1	7
Robot sessions completely finished	5	5	0
Robot sessions not finished	14	5	9

Figure 13: Feedback in Get up and g test.

Finally, it's necessary to emphasize that in both centers care the patient profile is different: in primary health center patients are less deteriorated than the users of the nursing home and that reality is reflected in our results, where more deteriorated patients didn't respect every indication done by the robot.

Our conclusion refers the Get up and go test is that more experiences are needed to correctly have an adequate develop to the pilot experience. We accept that the robotic platform is very sensible to the characteristic of the pilot's room (as the natural light, specificities of the chairs, etc.), the degree of inclination in the Kinect camera, etc.

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