Integrating the users in the design of a robot for making Comprehensive Geriatric Assessments (CGA) to elderly people in care centers

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***Abstract*— Comprehensive Geriatric Assessment (CGA) is a multidimensional and multidisciplinary diagnostic instrument that helps provide personalized care to the elderly, by evaluating their physical and mental state. In a social and economic context of growing ageing populations, medical experts can save time and effort if provided with interactive tools to efficiently assist them in doing CGAs, managing standardized tests or data collection. Recent research proposes the use of social robots as the central part of these tools. These robots must be able to unfold all functionalities that questionnaires or motion-based tests require, including natural language, face tracking and monitoring, human motion capture and so on. But another issue is the robot's acceptability and trust by the end-users, both patients (elderly people) and clinicians: the robot needs to be able to engage with the patients during the interaction sessions, and must be perceived as a useful and efficient tool by the clinicians. This paper presents the acquisition of new user requirements for CLARC, through participatory and user-centered design approach, to inform the improvement of both interface and interaction. Thirty eight persons (elderly people, caregivers and health professionals) were involved in the design process of CLARC, based on user-centered methods and techniques of Human-Computer Interaction discipline.**

I. INTRODUCTION

The United Nations (UN) has estimated that by 2050 one out of every five people will be over 60 years old. The number of elderly people is increasing every day all around the world [1]. In this context, the necessary requirement and challenge is to design new and innovative models to help elderly people achieve healthy aging and maintain their autonomy. The development of personalized treatments and long-term follow-up plans need to be settled based on a continuous evaluation of the patient's state of health. Proposed by Dr. Marjory Warren in the late 1930s [2], Comprehensive Geriatric Assessment (CGA) is the multidimensional diagnostic instrument designed to capture data on the medical, psychosocial and functional capabilities and limitations of elderly people.

CGA differs from standard medical evaluation in three basic ways: (i) it focuses on elderly people with difficult problems; (ii) it emphasizes functional status and quality of life; and (iii) it usually takes advantage of an interdisciplinary team of experts. A typical CGA session takes about 3 hours of clinician's time. Some of the activities require the presence of the clinical staff, but others, particularly the multidimensional assessment, are standard tasks that are possible candidates for automation and/or parallelization. The hypothesis is that delegating part of the CGA to a robot will allow clinicians to focus on activities with more added value, like deciding, together with the patient and relatives, the appropriate care plan. This is one of the Public end-user Driven Technological Innovation (PDTI) challenges proposed by the ECHORD++ project[1]. The CLARC project, presented in this paper, is one of the approaches funded by ECHORD++. It is focused on the use of robots in CGA.

CLARC implies multiple challenge tasks, not only related to the robot and its interaction with the end-users, but also with the deployment of a local node (with its local database and interfaces) connected to the Hospital Information System (HIS). However, apart from these functional aspects, the authors are convinced that the success in the proposal is based on the active participation of all end-users (patients, caregivers, nurses, geriatrics experts, hospital managers...) in the design of the different parts composing the full system. This paper describes the efforts made within the project to integrate in the design loop the user requirements (feedback, opinion, preferences of the end-users) about some key questions: How can the robot inspire trust in elderly and clinicians? How can the robot interfaces be improved in terms of usability and accessibility for disabled and elderly? What appearance factors do elderly people value in robotic assistants during CGA tests? Thus, after briefly reviewing the CLARC system in Section II, we present the usage concept (Section III). Then the user-centered methodology, the study design and main results are detailed in Sections IV and V, respectively. Finally, section VI concludes with the main insights and future work.

II. THE CLARC SYSTEM

Figure 1 shows an overview of the complete CLARC system. It is divided into two differentiated subsystems and four interfaces. The physical interaction with the patient is embodied in the CLARC robot. Currently, this robot is based on the MetraLabs SCITOS G3 [3]. The platform (Fig. 2)

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[1] http://echord.eu/pdti/pdti-healthcare/

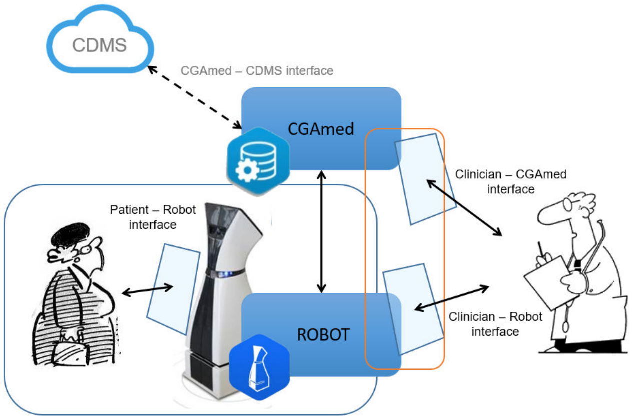

Fig. 1. Overview of the CLARC system.

has been upgraded with extra sensors to be able to drive and record CGA tests, and to interact with patients and relatives using speech and tactile channels. It also needs to interact with the clinicians, who should react to possible on-line notifications and/or alarms autonomously generated by the robot. Data related to patients and tests are stored in the CGAmed (Fig. 1), a data management system connected with the Clinical Data Management System (CDMS). The CGAMed allows the clinician to setup the tests to be performed (i.e. the daily agenda of the robot). Then, the robot can conduct the tests autonomously and store the results in the CGAMed database. Finally, the clinician will use this CGAMed interface again to review the session outcomes and create a new care plan and design the patient's follow-up.

III. USAGE CONCEPT

A. Robot Services for CLARC

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, 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 (mainly voice and touch-screen, see Figure 3).

User studies performed at one of the partners' Living Lab, the ActivAgeing Living Lab, analyzed other desirable (but optional) services: the robot could navigate to the reception desk and offer to accompany the patient to the test location, move autonomously from one room to another, synchronize its agenda with other robots to attend the patients efficiently, or offer higher-level interactive capabilities (such as eye contact, attention sharing, body gestures or touch). These research questions are currently being refined to redesign

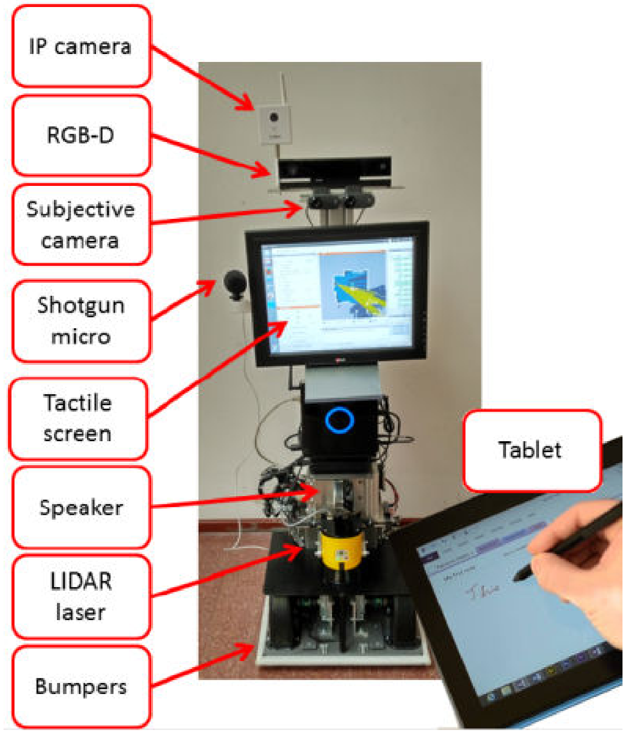

Fig. 2. Prototype of the CLARC robot and employed sensors.

Fig. 3. CLARC robot driving the Barthel test.

the use case and identify precisely the actions that the robot should perform. User tests focused mainly on the 3 tests currently implemented on the robot.

1) The CGA Tests: CLARC is currently able to perform three tests. Functional status is measured by activities of daily living (ADL) through the Barthel's Index Rating Scale [4]. 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 is currently able to ask questions using 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. Mini-Mental State Examination (MMSE) is one common tool used in cognitive function assessment [6]. 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). Finally, the Get Up & Go test [5] 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. The physician can use CGAMed interface to monitor the tests on-line , and also to access the results once the test is finished (see Section III-C).

B. User Groups

We identified four central user groups: elderly people, caregivers, health professionals (geriatric experts, physiotherapists, nurses...), and health-care center managers. Coherent with the Living Lab approach, all the actors concerned by the issue of CGA - and not only elderly patients - are involved in the design process. Complementary methods, depending on the research agenda, were used to gather insights: user tests with predefined tasks (make a test with the robot) followed by debriefing interviews, semi-directive in-depth interviews with health professionals, focus groups. At that stage, the focus was on gathering feedback about the robot performing the tests, including the main interface (see section below). All the end-users - whether seniors, elderlies or health professionals - tested the robot's performing the Barthel, Get up and Go and MMSE tests.

C. Concept of the User Interfaces

As Figure 1 shows, we specified, designed and developed three user interfaces (there is a fourth one for connecting the CGAmed to the CDMS, but this is a machine-to-machine interface based on the HL7 protocol). Elderly patients and caregivers interact with the robot using voice and tactile accessible and usable interfaces. The tactile option is currently implemented in a touch-screen on the torso of the robot. Touch-based interaction can be designed to be accomplished easily by elderly people [7].

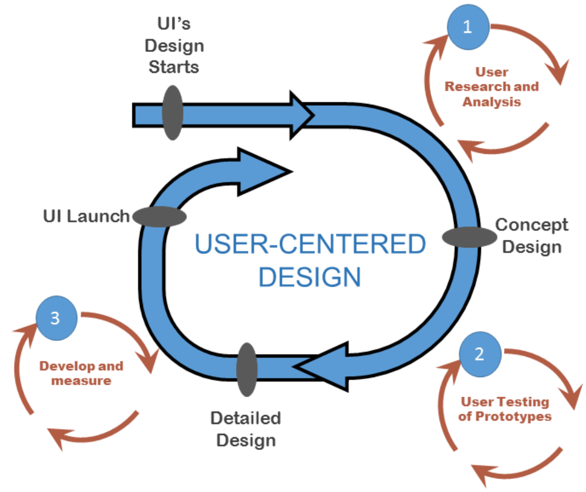

Fig. 4. User-centered Methodology. Designing User Interfaces (UI).

IV. USER-CENTERED DESIGN OF CLARC'S USER INTERFACES

Different research areas: Human-Computer Interaction (HCI), Software Engineering (SE), Human-Factors Engineering (HFE) and Assistive and Rehabilitation Technology (ART) disciplines defined different guidelines to follow for designing human-robot interfaces. Our research work is based on these disciplines, using an iterative methodology, following a user-centered approach by involving the user during each phase of the design and development of the system, as presented in Figure 4, and detailed in section V.

The first phase of the methodology consists of analyzing and researching the users' characteristics, limitations and needs. During the first phase, we reviewed the literature and analyzed recommendations, guidelines, standards and heuristics related to elderly users and disabilities. Based on that, a first functional-based prototype of the user interfaces was developed (concept design), taking into account accessibility and usability issues. During the second phase of the methodology, which is described in this paper, the CLARC users (stakeholders) are involved in the design decisions, through a user study. This informs the development of another version of the interface (detailed design), and finally the usability and accessibility level of the interfaces can be measured before launching them. This process is therefore iterative. The next subsection (IV-A) explains how the first phase is carried out and Section V details how users have participated in the design process during the second phase. Authors are currently working in the third phase, developing a new system interface according to the requirements understanding acquired during the research work presented in this paper.

A. Accessibility and Usability of User Interfaces

The importance of developing accessible and usable user interfaces is nowadays well known and commonly accepted. An accessible software is software that every person (people with disabilities, elderly people, people in special environments, etc.) can perceive, understand, navigate and interact with [8]. A usable software is a software that accomplishes the goals of the users in terms of factors such as ease-of-use, visual consistency, clear interface and content, defined process for evolution, etc. [9]

For the CLARC project, the design of accessible and usable interfaces is especially necessary, due to fact that the main users interacting with the robot are elderly people. Elderly people usually present limitations interacting with software due mainly to the impairments (natural changes) associated with ageing (vision, dexterity, hearing and cognitive impairments), and the peoples ability to use the new technology.

During the first phase, the literature review helped us to adapt the interfaces according to our users' specific needs. Though Nielsens 10 usability heuristics for designing user interfaces [10] (gold standard in HCI), these heuristics are not enough to completely consider the users needs, because they are focused on the typical user - users without physical or cognitive impairments[11]. Fortunately, several research groups have focused their research on disability issues and accessibility in HCI. For instance, the W3C consortium [2] and the Nielsen Norman Group [12] are focused on web accessibility. Bergman and Johnson [11] or BBC guidelines [13], among others, have addressed accessibility in computing applications. Specifically focused on the necessities of older adults, the WAI-AGE project [3] and Kumiawan and Zaphiris [14] proposed guidelines for helping web developers to design web user interfaces (UI) taking into account their special needs, and Vanderheiden and Vanderheiden Guidelines [15] help to design consumer products to increase their accessibility to persons with disabilities or who are ageing. Finally, Tsui guidelines [16] are focused on accessible user interfaces for telepresence robots. Moreover, our work have been based on European or International regulations, such as ISO 9241-171, 2008 [17] or ISO/IEC 13066-1, 2011 [18] dealing with accessible interfaces. Some of them have even become standards and are the basis of different laws worldwide, which protect the rights of people with disabilities, such us ISO/IEC 40500, 2012 [19]. Based on this list of recommendations, the first prototype of CLARCs interfaces has been implemented from January to June 2016 (Phase I of the project). From a functional point-of-view, the robot was able to conduct three different CGA tests (see Section III-A.1), that were tested during the user study described in this paper.

[2]W3C Consortium: https://www.w3.org/Consortium/

[3]WAI-AGE project from W3C Consortium: https://www.w3.org/WAI/WAI-AGE/

V. INVOLVING THE USERS IN THE DESIGN PROCESS

Based on the working prototype, a four-day participatory workshop bringing together senior end-users, health professionals and researchers, was organized in order to capture user requirements.

The main objective of the workshop was to acquire new requirements for the CLARC system, trying to collect the end-user feelings, opinion and satisfaction when interacting with the first prototype of the CLARC system.

The workshop was conducted at the Activageing Living Lab[4]. This platform offers an operational apartment environment attached to a high-technology-equipped control room, and a creativity lab.

The observational research approach complementarily combined a collection of common user-study techniques widely used in HCI research:

- In-depth qualitative interviews and focus groups: to capture user requirements.
- User tests followed by debriefing interviews: to collect valuable feedback related to interaction problems.

A. Interviews and focus groups. Design

This section presents the design of the in-depth qualitative interviews and focus group sessions.

1) Objectives: The main aim of in-depth 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.

2) Participants: Twenty persons participated in the focus groups, 10 people in each group. There were 14 seniors and 6 health professionals. The seniors were 12 women and 2 men. The age range was : 60-70 years: 5 participants, 70-80 years: 5, 80-90 years: 2. The health professionals were 4 women and 2 men: 2 nurse trainers specialized in geriatrics, a coordinating nurse in a retirement home, a retirement home director, a physiotherapist executive in a functional rehabilitation centre and a director of a company providing medical-technical services at home.

There were six in-depth interviews made with health professionals. Two of them were at the living lab, where a geriatician and a nurse managing a geriatric day care hospital could see the robot before being interviewed. Three of the interviews were in the professional's workplace: a coordinating nurse in a retirement home, a geriatrician director of a prevention centre and a nurse trainer who has worked as a coordinating nurse in a retirement home. Finally, one interview was conducted on the phone: a physiotherapist. Four of these professional are women and two of them are men.

[4]http://www.activageing.fr/

3) Evaluation Process: During the focus group sessions, different research questions were collectively examined. The reflection was voluntarily large with brainstorming at the beginning, focusing more closely with post-it sessions: What does geriatric evaluation evoke for you? What is an ideal medical consultation? How can the robot inspire trust to both patients and clinicians - in terms of appearance, mobility, speech? What type of form would be the most appropriate (on a continuum from ballish to humanoid)?. Finally, the focus group's participants had the opportunity to see the actual look of the robot and to test it in real-life situations. Then they help us to design the final look of the robot.

During the interview sessions, profesionals were asked about their current practice in doing CGA: the process at their hospital, the collaboration/delegation with other health professionals, data collection and sharing (paper and/or digital patient records), what information is needed to make a diagnosis, the type of interaction with the patients (is/should there be more time for the relational aspects), their opinion about the added value of the robot in their practice.

B. Interviews and focus groups. Results

This section summarizes the main results emerging from in-depth interviews and focus groups conducted during the workshop. The main insight of the interviews is the unanimously perceived added value of the robot: All the health professionals agreed that the robot would allow them to save time, either allowing more relational work or receiving more patients. Many differences appeared in the the way the CGA process itself is done, depending on country and type of institution, showing the necessity of the robot to adapt to the organisational context. The main insight from the focus group is the need for the patient to have the feeling of being known and recognized as a person (not as a patient record number), either by the clinician according more attention, or, concerning the robot, having the feeling that it is not just a machine. The three main keywords concerning an ideal consultation are : time, trust and empathy, which interestingly apply both to clinicians and the robot. The general desired shape for the robot is roundish, but without any human characteristics: only one participant chose the humanoid shape. Another insight from the focus groups was related to the robot's look. Participants were asked to choose individually between 8 shapes on a continuum (from a ball - shape 1 to a very humanoid one with arms and legs - shape 8), the one they liked best and the one they liked least, and to justify their choice. The two preferred shapes are No 4 and No 5 - intermediary shapes: a head on a round body, but without any human-like features. This choice was justified by the smoothness, practicality in mobility, fusion between brain and body.

C. User tests. Design

This section presents the design of the user test and debriefing interviews.

1) Objectives: The main objective of the user test was to collect valuable feedback related to the user interface and problems that users faced when interacting with the first prototype of CLARC. The tests were focused mainly on 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 (see section below for more details). This technique is very useful for acquiring new user requirements by detecting problems in user interfaces, providing qualitative data [9].

2) Participants: Sixteen users performed the user tests and debriefing interviews (Barthel: 13 users; Get up and Go: 11 users; MMSE: 3 users). Two were health professionals, the others were seniors. Among the seniors, there were 10 women and 4 men. They were aged between 62 and 93 years old, divided as such : 60-70 years: 5 participants, 70-80 years: 4 , 80-90 years: 3 participants, +90 years: 2 . The ladies aged 90+ were accompanied to the lab by their daughters who are their informal caregivers, and performed only the Barthel test. One did the whole test alone, the other received her daughter's help at some points. In order to test the speech technologies in two languages, the Barthel and Get up and Go were performed in French, the MMSE in English (2 of the 3 users were native speakers).

3) Evaluation Process: The user tests consisted of users and health professionals performing individual tests with the CLARC robot in the living lab's apartment. Each test was video recorded in multi-camera, to capture in detail what users actually did - robot and screen interaction - and also the outputs produced by the system. Before carrying out the test, a user-test expert accompanied the user to a room where the CLARC robot was and explained briefly what the test consisted of (interact with the robot, answering the test questions and/or carry out the requested tasks). Subsequently, the expert left the room (robot and user kept in the room - see Figure 3-, in one case, joined just by a family member who would help the user to perform the test). Observations were made by two usability experts : taking notes during the user-robot interaction (unexpected events, doubts during the interaction, etc.) in an indirect way (from the adjoining control room, so the user was not disturbed or influenced during the interaction). Participants performed either Barthel together with Get up and Go, or MMSE alone. Then, the tests were immediately followed by 20-minute debriefing interviews to collect users' feedback and suggestions.

D. User tests. Results

This section summarizes the main results emerging from the user tests conducted during the workshop. The user-requirements 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.

VI. CONCLUSION AND FUTURE WORK

The user-centered approach adopted for the development of the CLARC system has 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.

Currently we are working on developing the 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. The next step is 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 during field trials in the geriatric hospital context.

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