Public end-user Driven Technological Innovation (PDTI)

Robotics for the Comprehensive Geriatric Assessment (CGA) Challenge

CHALLENGE BRIEF – RELATED TO THE ECHORD++ CALL FOR R&D PROPOSALS IN HEALTHCARE

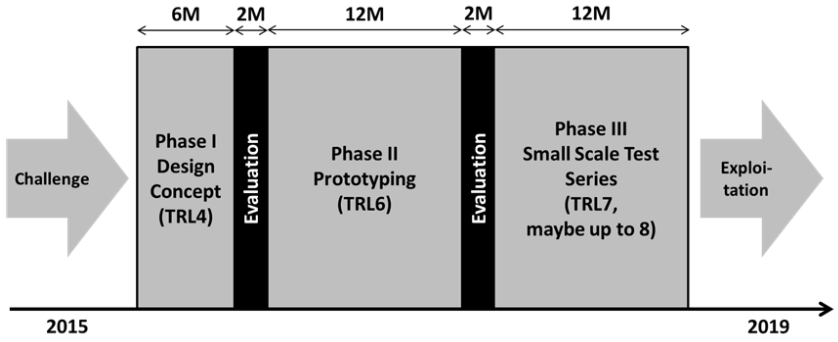
Version 4.5.2015

Table of contents

1 Summary

In Echord++ the Public end-user Driven Technological Innovation (PDTI) in Healthcare is seeking for technical solutions to improve the Comprehensive Geriatric Assessment (CGA).

The PDTI scheme is structured in 3 phases: 6 months for the first phase and 12 months for the second and third one. The main parameters and the timeline is shown in the diagram and the table below.



	Phase I Design concept	**Phase II** Prototyping	**Phase III** Small scale test Series
No. of R&D consortia	3	2	2
Funding per consort.	50.580 €	174.360 €	350.100 €
Duration	6 months	12 months	12 months

The expected results of the work are systems which have to manage specific tasks of the CGA processes to allow Health Professionals to perform CGA in an easier way and with more quality. The expected systems have the following main characteristics:

- Ability to do autonomously some functional or mental tests instead of the health professional, discharging and enabling him/her to focus in other issues of the CGA process.
- Accompanying the Health Professionals during clinical interviews recording or displaying information avoiding communication barriers (desk, screens, computers, etc.). That shall allow Health Professionals to be focused on the patient and relatives, maintaining visual contact.
- Gather patient's data in different formats: video of gait, audio of voice during tests, etc.
- Record the data in an open format to interoperate with other systems

The expected outcome of the three phases is summarized in the following table.

Stage I (first 6 months)	**Stage II (month 7-18)**	**Stage III (month 19-30)**
Concept of whole system First prototype, mainly to assess the look-and-feel, but mock-up functionality	Usable prototype with main functionalities implemented in the first version. First tests with end-users possible, but supported by the developers	Fully functional system ready to be tested in practice with very limited help of the developers.
Mock-up of Barthel [1]and Get-Up and Go tests.	Implementation of Barthel and MMSE test, as well as the Get-Up-and-Go test.	Full implementation of Barthel, Lawton, Pfeiffer, MMSE, Yesavage, as well as Get up and Go, Tinetti Gait, Tinetti Balance tests.

To achieve the different functionalities, the consortia should cover the following complementary skills and competences: Multi-modal human-robot interaction, dialogue-based systems, health care expertise, etc. Additional competence in teleconsultation/telesurveillance/collaborative platforms might strengthen the consortium.

[1] For the definition of these tests, please refer to the annex.

2 Introduction

The profile of aging in the world is changing dramatically since the second half of the 20th century and will continue changing in the future. The average life expectancy at birth has increased from 47 years in 1900 to over 78 years in 2008. There are approximately 810 million persons aged 60 years or over in the world in 2012 and this number is projected to grow to more than 2 billions by 2050.

There is a strong association between the presence of geriatric syndromes (cognitive impairment, falls, incontinence, vision or hearing impairment, low body mass index, dizziness) and dependency in activities of daily living. However, decline in function and loss of independence is NOT an inevitable consequence of aging. Given the high prevalence and impact of chronic health problems among older patients, evidence-based interventions to address these problems have become increasingly important to maximize both the quantity and quality of life for older adults. In this context health services for older persons are becoming increasingly important, and Comprehensive Geriatric Assessment (CGA) is a clinical management strategy, used around the world, that gives a framework for the delivery of interventions which address relevant and appropriate issues related to an individual frail older patient.

CGA determines an elderly person's medical, psychosocial, functional, and environmental resources and problems linked with an overall plan for treatment and follow-up.

2.1 Healthcare burden of elder population

Ageing has profound consequences on a broad range of economic, political and social processes. First and foremost is the increasing priority to promoting the well-being of the growing number and proportion of older persons in most countries of the world.

Ageing is also partly the result of the trend toward longer and generally healthier lives of individuals, but because chronic and degenerative diseases are more common at older ages, they result in an increased prevalence of non-communicable diseases at the population level. Last but not least, as societies' age, they also bring about changes in the living arrangements of older people vis-à-vis younger family members, and in the private and public systems of economic support for older persons.

Population ageing and development[2]

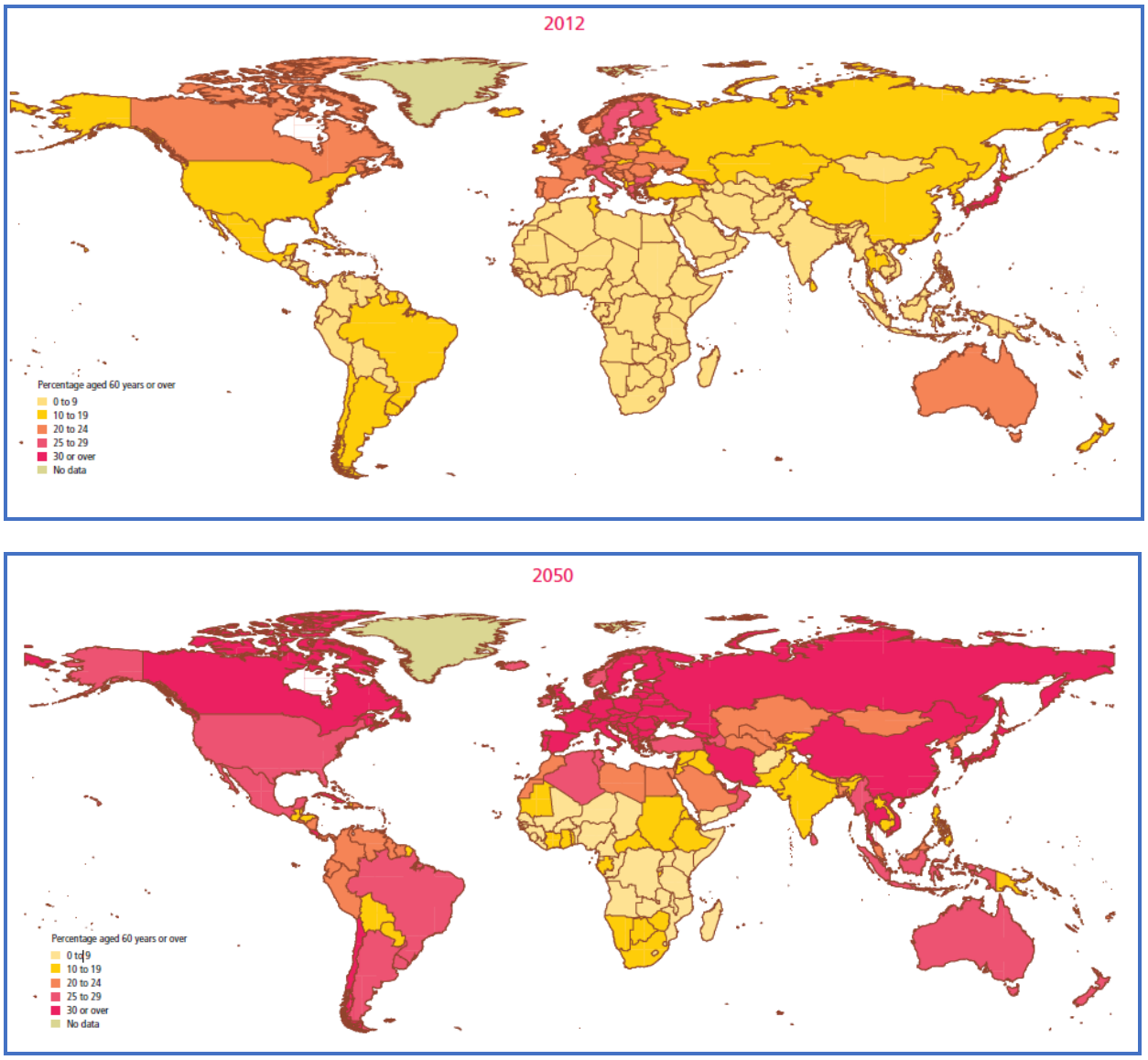
Proportion of the total population aged 60 years or over: in 2012, one out of every nine persons in the world was aged 60 years or over. By 2050, one out of every five persons is projected to be in that age group. The proportion of the total population that is 60 years or older is much higher in the more developed regions than in the less developed regions: one in five persons in Europe; one in nine persons in Asia and Latin America and the Caribbean; and one in 16 persons in Africa.

Share of persons aged 80 years or over: the older population is itself ageing. Currently, the oldest old population (aged 80 years or over) accounts for 14 per cent of the population aged 60 years or over. The oldest old is the fastest growing age segment of the older population. By 2050, 20 per cent of the older population will be aged 80 years or over.

Proportion of older persons who are living independently: living independently, that is, either living alone or only with one's spouse or husband, is rare among older persons in developing countries, but is the dominant living arrangement in developed countries. An estimated 40 per cent of the world's older persons live independently, with no discernible difference by sex. The gap in the proportion liv-

[2] Population ageing and development 2012. Department of Economics and Social Affairs of United Nations. www.unpopulation.org

ing independently between the more developed regions and the rest of the world is remarkable. Almost three quarters of all older persons in the more developed regions either live alone or only with their spouse compared with only a quarter in the less developed regions, and just over 10 per cent in the least developed countries. The predominance of independent living among older persons is likely to increase as the world's population continues to age.



2.2 Which are the benefits of CGA?

As shown in figure 1 below, CGA has demonstrated benefits in different areas of health and social care processes:

- improving the **diagnostic plan** by appropriate selection of diagnostic tests to be performed or, to be avoided;
- giving **right and proportional therapeutic decisions** to patient's expectations and clinical status (avoiding over or insufficient treatment). It also reduces complications during hospitalization (like delirium and intrahospitalary infections) and less mortality;
- **increasing** patient's **functional autonomy at hospital discharge** and reducing need for income in nursing homes;

- selecting of **the most adequate level of care for the patient** (hospitalization in acute or sub-acute care units, day hospital care, or ambulatory care).

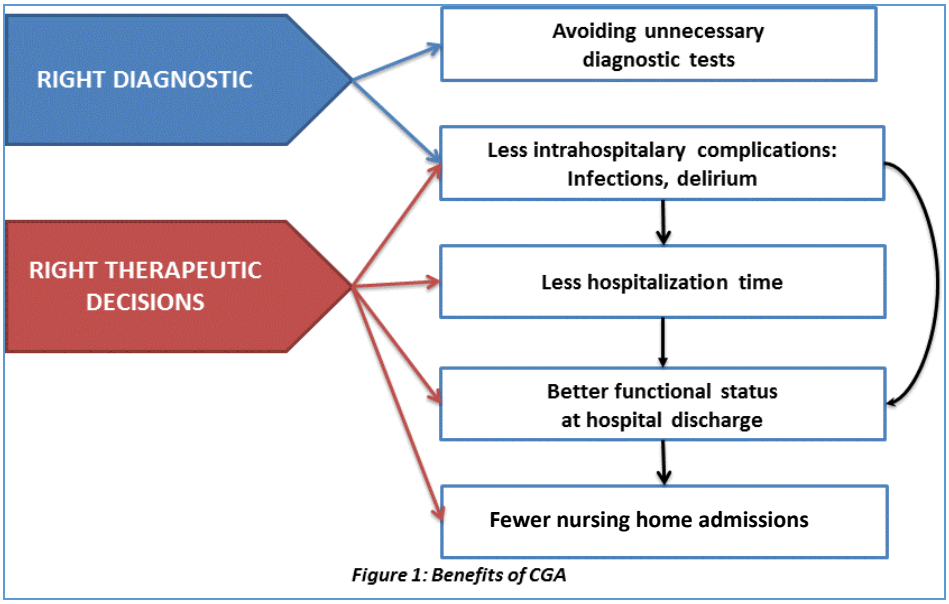


Figure 1: Benefits of CGA

Economic impact on costs from the above benefits are obvious and all of them have been reported at the different settings where CGA has been evaluated: ambulatory care services, hospitalization units, and urgency services.

Usually, the process requires professionals' to use supporting devices (frequently a computer). These devices sometimes impede the interaction between Health Professionals and patients/relatives: Health Professionals need to pay attention at patients/relatives but also have to introduce and manage information in the supporting devices loosing visual contact; that interrupts communication and, many times, patients feel that health professionals pay more attention to the computer than to them. Screen, tables and other furniture are barriers and impact adversely in visual contact during interviews.

Cognitive tests performed by professionals may cause anxiety in patients; they know that they are being evaluated and results will affect important issues as his autonomy and ability to stay at home. In that sense, a robotic system is felt neutral by patients so they should be considered an alternative in cognitive tests.

3 Comprehensive Geriatric Assessment (CGA) – State of the art

3.1 What is Comprehensive Geriatric Assessment (CGA)?

CGA is more than an assessment process of an individual; it is an intensive interdisciplinary process to assess functional status of elderly including medical, psychosocial, and functional limitations of frail elderly people; it is used to develop a coordinated plan to maximize their overall health.

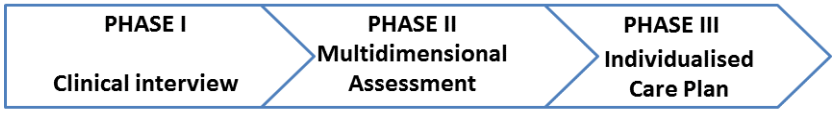
CGA implies the evaluation of all the relevant issues related to patient status which have to be considered to perform a successful care plan for an elderly or old-age patient for any health or social inter-

vention; it comprises functional, mental, social, and clinical assessment (including nutritional status). Thus, CGA is individualized and needs to be updated periodically (usually every 6 moths). Since patient and relatives perceptions about the patient's performance on functional or daily basic activities like cooking or medications control may differ (especially in cases of cognitive problems where the patient is not aware about its limitation), in Phase 1 and Phase 2 activities the health professionals need to gather information from both patients and relatives and, with patient's consent, some interviews or tests may be performed separately. Therefore, doing tests in a parallel way (patient and relative in separated rooms) is very useful because the total time for the process waiting time for patient and relatives are minimized. CGA typically results in the formulation of a list of needs and issues to tackle, and develop an individualised goal-driven care and support plan, tailored to the patient's needs, wants and priorities that, ultimately, provides and coordinates an integrated plan for treatment, rehabilitation, support and long-term care.

3.2 What is the process?

Phases of CGA process

The CGA process involves three main groups of activities to reach the objectives: the clinical interview, the assessment and the care plan.



Phase 1: Clinical interview

The clinical interview is the initial phase of the process where patients and relatives meet the healthcare professionals and discuss the main problems and worries concerning the elder while overviewing his personal health issues (allergies, diseases, surgeries and medications).

Phase 2: Multidimensional Assessments

During this phase multidimensional assessment tests are performed to assess the functional, mental and social status of the elderly person. The usual scenarios where the CGA assessments are performed: are hospital settings: Hospitalization Units for income patients, Day Care Hospital, or Ambulatory Care Units for ambulatory patients. This is the main functionality of the envisaged technical solution.

A detailed description of the functionality can be found in section 4.

Phase 3: Individualised care plan

This is the most important phase of the CGA process where healthcare professionals evaluate patient's information gathered during the previous phases and devise a personalized care plan adequate to patient and relatives' profile.

The individualized care plan includes: additional diagnostic tests, therapeutic recommendations (medications, rehabilitation treatment, cognitive stimulation, etc.) and the more suitable setting for the patient to execute the care plan (ambulatory care unit, day care hospital, or hospitalization units).

3.2.1 CGA tests

The wide range of issues to assess in CGA in order to evaluate functional and mental status of a frail elder requires an organized process to get and organize information. In this sense, at present, existing formal tests are the most objective and valuable tools used by health professionals to objectively evaluate the status of patients.

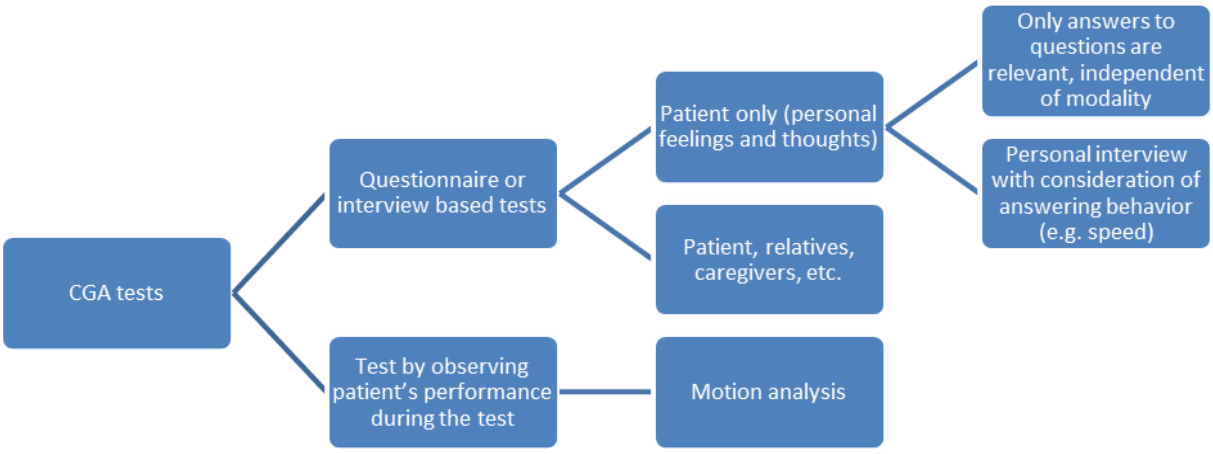
CGA tests gather quantitative information that can be easily shared with other Health Professionals. This information must be updated periodically to follow patient's evolution from a quantitative point of view. Both subjective assessments and quantitative information have to be considered during CGA process to allow Health Professionals to perform a successful CGA.

To evaluate patient's potential for improvement and his evolution during the care process, the tests are applied in different moments to analyze different status:

- **Basal status**: how the patient was when he or she was stable (for example 6 months before the date when the medical interview is performed).
- **Current status**: how the patient is at the moment of medical interview. His interview is repeated in regular intervals, e.g. every 6 months, to allow assessment of the development.

From the time of the first clinical interview on, the tests are repeated during the care process to evaluate the patient's improvement or deterioration. Therefore, all data related to the individual tests and results over time are recorded and an analysis of the development over time has to be performed by the system. The resulting information can be used to estimate the further development and to adapt the care plan and therapeutic recommendations.

The tests can be classified according to the following scheme:



Regarding the cognitive assessment, **brief** tests (screening test) for dementia, lasting between 5 and 15 minutes, are performed either by medical doctors or nurses and need to be done by the expected robotic system .These tests require advanced interfacing modalities and advanced technical cognition (artificial intelligence) because the test's questions are usually open and there is a need to interpret and codify the patient or relative's answers. However, a useful alternative may be to change the questions in closed ones with pre-defined answers where patient or relatives may select a specific option through

interaction with a device like a touch screen. Behavioral analysis during cognitive test may be interesting.

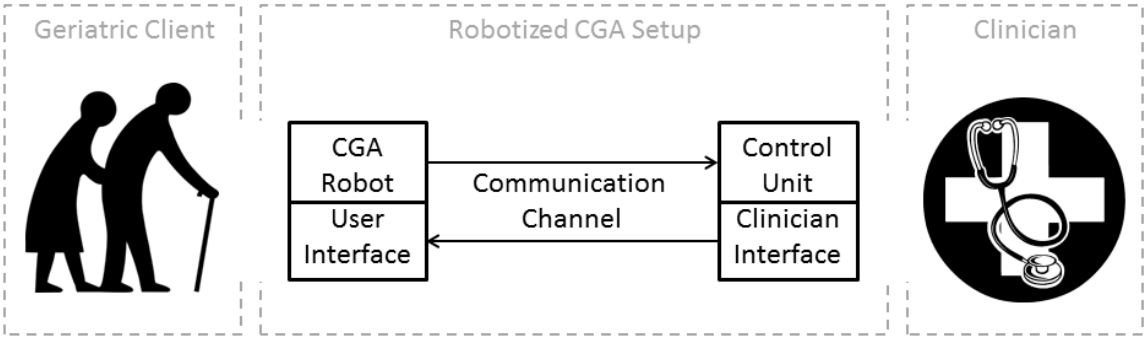
There are a lot of tests available to perform the assessment in Phase 2 of CGA process. Table 1 illustrates the main characteristics of the most common tests, detailed can be found in the annex.

Table1: Main characteristics of GCA tests

Test	Evaluated issue	Current way of assessment	HP	Score's range	Hospital's setting
Functional tests					
Barthel Index	Performance on basic activities	Face to face interview	MD, N, OT	0-100	ACU, DCH, HU
Lawton Index	Performance on instrumental activities (more complex than basic activities)	Face to face interview	MD, N, OT	0-8 (F), 0-5 (M)	ACU, DCH, HU
Time Up and Go test	Gait and balance	Visual observation	MD, P	Time (seconds)	DCH
Tinetti test Gait	Gait	Visual observation	MD, P	0-9	DCH
Tinetti test Balance	Balance	Visual observation	MD, P	0-26	DCH
Mental tests					
Pfeiffer test	Screening test for dementia	Face to face interview	MD, N	0-10	ACU, DCH, HU
MMSE test	Screening test for dementia	Face to face interview	MD, N, Psyc	0-30	ACU, DCH, HU
Yesavage test	Screening test for depresion	Face to face interview	MD, N, Psyc	0-15	ACU, DCH, HU
Social test					
Zarit test	Caregiver's emotional burden	Face to face interview	MD, SW	0-88	ACU, DCH
Clinical tests					
Face Pain Scale	Pain intensity	Face to face interview	MD, N	0-6	ACU, DCH, HU
Analogic Visual Scale	Pain intensity	Face to face interview	MD, N	0-10	ACU, DCH, HU

MD: medical doctor; N: nurse; OT: occupational therapist; P: physiotherapist; Psyc: neuropshycologist; SW: social worker
ACU: ambulatory care unit; DCH: day care hospital; HU: hospitalization unit

3.3 State of the art analysis for "Robotized comprehensive geriatric assessment"



Currently there is no robotic system known in the market which assists clinicians in taking CGA. Few specific software architectures have been introduced [3]for online application of clinical tests. However, they usually require the direct collaboration of patient and online availability of the health professional. Functional tests like Tinetti or Berg tests cannot be performed through these platforms because the evaluator needs to move beside the patient to get a successful assessment.

[3] Rocha A, Martins A, Freire Junior JC, Kamel Boulos MN, Vicente ME, Feld R, et al. Innovations in health care services: the CAALYX system. Int J Med Inform. 2013 nov;82(11):e307–320

4 Functional & technical specifications (requirements)

4.1 Functional Requirements

Although the main activities a robotic system in CGA may perform autonomously are in Phase 2 (Multidimensional Assessment) of the CGA process, the system should also help to improve the process in other phases. All the problems of CGA described in section 3.2 may be considered targets for improvements.

The new solution to the CGA challenge must help the staff at the geriatric department to decrease the amount of time spent on the clinical interviews and on the geriatrics tests in order to have more time with the patient and relatives to decide on an individualized care plan (that is the final and most important phase of CGA's process). Furthermore, the new robotic solution should assist the staff in order for them to be able to focus more on the patients directly (e.g., rather than focusing on typing). CGA process is not continuous and there are interruptions due to the special characteristics of tests. For instance, some tests (especially balance and gait tests) have to be performed in specific settings outside the office where interaction patient-professional is being performed.

To achieve this in an intuitive and socially acceptable way of interacting with the elderly, the patient's position and orientation during the tests should not be constraint too much by technical requirements. This can lead to the need for adaptation to the situation which would exploit mobility capabilities of the system to make gestures, body language, facial expressions, synchronization with stimulation, verbal expression, breath, etc. better observable. This will be also recorded for later comparison with the current state of a patient. The extraction of such multimodal signals may be required for patients with mild cognitive impairment such as attention deficit disorder, apathy, etc. to capture emotions and gestures, posture, etc. or chronic disease or mild disease (minor injuries). This information will be used by the health professional during the cognitive assessment. The sensor system in this way would become less invasive and would place the tests within a framework of more natural activity. The ability to position the system in a specific way also helps increasing the quality (signal / noise ratio) and would also simplify the image and/or audio processing for specific tests. In addition, new test types could be supported, e.g. exercises to find a particular place or a chain of activities (turn in place and return Mr. X's office). Furthermore, mobility can also be a component of stimulation to the patient as part of cognitive exercises.

Hence, the functionalities and system properties for the robotic solution for CGA are:

Technical requirements:

- A robotic device should be able to manage autonomously the execution of some tests and assist the Health Professionals discharging and freeing up time for them to focus on more important activities like phase 3 of the process. Furthermore, discharge also should decrease health professionals' tiredness or fatigue perception as consequence of doing tests in a repetitive and mechanical way.
- Ability to ask patients/relatives questions of selected tests;
- Selection of tests by professionals to include in an individual CGA. A predetermined flow chart for test sequence may be considered, including the option to skip some tests[4];

[4] Adapting the tests for the use of closed questions and pre-specified answers will be considered.

- Easy configuration and development / implementation of new tests with minimal (ideally no) need for assistance by robotics or computer science experts
- Doing tests in a parallel way (patient and relative in separated rooms) might be very useful because the total time for the process can be reduced and the waiting time for patient and relatives can be avoided (see section 5 Use Cases)
- Ability to interact by speaking and natural language processing (even in case of slightly slurred speech) to limited extend, interpreting a set of standard pre-defined answers and with multi-language support. Alternative mode of interaction like touch screen tool may be considered.
- Ability to interpret and codify patients/relatives answers in spoken language and by touch screen input of selected tests;
- Ability to calculate tests scores based on codified information. The Health Professional has to be able to modify or correct tests scores;
- Ability to display information and results in a user-friendly way (dashboard style). Professionals usually do not need to see all detailed scores of tests; they would have a global vision of total scores and deepen when needed.
- Usually, clinical information is registered only in text format into clinical records. However, availability of clinical information in other formats may be very valuable. In this sense, Health Professionals would like to see patients' performance when walking; for instance, a video may be useful to compare patients' performance at the beginning and at the end of a rehabilitation process. Availability of patient's facial expression or voice before and after an antidepressant treatment may be another issue to be considered by Health Professionals to evaluate effectiveness of prescribed treatments.
- The solution must be able to evaluate patients' performance during walking tests (like gait and balance tests): recording the patient's performance, using standard components for motion analysis to the extent possible. A mobile platform may be deemed helpful to maintain sufficient visibility for the video and audio recording of patients during the tests.
- The solution must be portable in order to be moved around at the clinic
- All data must be stored safely and in an open format.

Overall system - Properties and non-technical requirements:

Mandatory:

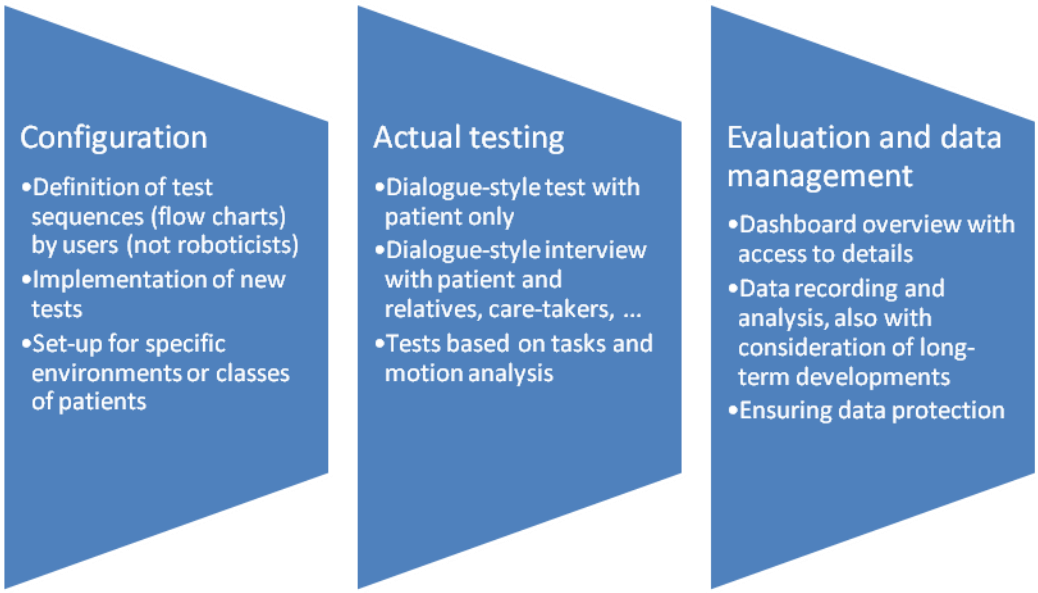
- The robotic solution should assist health professionals offering the possibility of relegating some tests, so that professionals shall be more focused on the other phases or tests improving the outputs of CGA's process.
- The design of the system must inspire trust both with the staff and with the patients and relatives. Patients have mentioned that the robotic systems should not seem dominant, e.g. by operating with humanoid/android hands.

Desirable:

- The solution should assist in clinical interviews, helping the staff to focus directly on the patient by having eye contact rather than looking into a computer screen. Also, the solution should help reduce the time spent on the clinical interviews, but still ensuring the quality and the proper data collection.
- The solution must be modular and scalable in order to ensure as big an international deployment to the extent possible.

- The solution can be built on already existing technologies as long as the RTD consortium has a legal agreement on further development of the existing technology. The consortium may also develop new technology for the CGA challenge.

Another way of grouping the required functionalities is shown in the following diagram: Functions can be grouped by different types of use.



Requirements and expected outcome at the different stages of the development according to the stages defined in the Guide for applicants[5]

	Stage I (first 6 months)	**Stage II (month 7-18)**	**Stage III (month 19-30)**
General requirements			
Overall system	Specification of overall system setup with geometric parameters, weight of the system, description of interaction modalities. One single prototype mainly with mock-up functionalities, see below.	Overall system prototype fulfilling the requirements described in Stage I, with all foreseen interaction modalities, even if not in final shape, but advanced enough to do a first evaluation with doctors, nurses, etc. as test users-	Small-scale test series (4 systems, to be used in the main hospital scenarios: ambulatory care units, day care hospital and hospitalization units. 1 additional system as backup and for tests) with all foreseen interaction modalities, actually being evaluated at the public bodies sites in an 28 days evaluation trial
Weight	The specified system must be portable by a normal human, the first prototype can be bigger/heavier, but needs to give an impression of the final one at the end of stage III.	The specified system must be portable by a normal human, the stage II prototype can be a bit bigger/heavier, but needs to give an impression of the final one at the end of stage III.	Prototypes meeting the specification, the portability has to be demonstrated.
Power supply	The specified system must be able to be operated both in battery mode for at least 8 hours, as well as in plugged-in mode, the first prototype can be powered by cable. For the final systems, inability to operate in battery mode may be an critical problem because the device will be used in patient's rooms or small places where plugging may be very complicated	The stage II prototype can be powered by cable.	The prototypes must be able to be operated both in battery mode and plugged as specified.
Language interface	Technical concept and prototype of a robust natural language interface which allows for multi-language support. Prototypes in stage I and II can use any European language (preferably English, Spanish, or Catalan), but the capability for multi-language support has to be demonstrated.	Fully functional Robust Natural language interface, ability to interact by speaking and natural language processing (even in case of slightly slurred speech). The demonstration can be done using any European language (preferably English, Spanish, or Catalan), but the capability for multi-language support has to be demonstrated	Fully functional Robust Natural language interface, ability to interact by speaking and natural language processing (even in case of slightly slurred speech). The actual tests will be in Catalan and/or Spanish, the addition of these language(s) will be done with the help of the public bodies and other supporting staff.
Touch-screen interaction	Mock-up of touch-screen based interaction for	Demonstration of touch-screen based	Full implementation of all dialogues

[5] See http://www.echord.eu/fileadmin/user_upload/Services/PDTI-call/Guide-for-applicants-2014-12-22.pdf

	all sorts of dialogues, for tests, configuration, and evaluation/data management. Other, yet easy to use and robust interaction modalities besides spoken language are also possible for the tests. They need to be able to be used if the natural language interface is not suitable, e.g. when a patient is not or only hardly able to speak. Also here, the multi-language issues apply in the same form as described above.	interaction for all sorts of dialogues in the prototype resulting from stage II, capability for multi-language support has to be demonstrated	which use the touch-screen mode, The actual dialogues will be in Catalan and/or Spanish, the addition of these language(s) will be done with the help of the public bodies and other supporting staff.
Motion tracking	Concept and exact specification of motion tracking system with planned analyses in context of the Get up and Go test and the Tinetti Balance and Gait tests	Implementation of the motion tracking component and prototype of the analysis software and the dashboard for this functionality, get up and go test	Full implementation of the motion tracking component with analysis software and the dashboard for this functionality for Get up and Go, Tinetti Gait, Tinetti Balance
Actual testing			
Dialogue (questionnaire)-based tests	Mock-up of the dialogue-based Barthel test	Implementation of the dialogue-based Barthel and MMSE tests.	Implementation of the following dialogue-based tests. Ideally: Functional tests: Barthel and Lawton tests. Mental tests: Pfeiffer test, MMSE test, and Yesavage test.
Tests based on motion analysis	Mock-up of the Get Up and Go test.	Implementation of the motion tracking component and prototype of the analysis software and the dashboard for this functionality, get up and go test	Full implementation of the motion tracking component with analysis software and the dashboard for this functionality for Get up and Go, Tinetti Gait, Tinetti Balance
Audio/Video recording	Proof of concept of the ability to record patients while they are performing the selected tests. Video recording is especially important for gait or balance tests, and audio and video for mental tests. The system should provide suitable point and field of view for the tests.	Full recording capability to be demonstrated	Full recording capability integrated
Evaluation and data management			
Patient-specific view	Mock-up of the dashboard for one patient's data including his development in test results, and access to raw data, such as answers given in a specific test or videos and other visualisation of the motion analysis.	First prototype of a dashboard for one patient's data including his development in test results, and access to raw data, such as answers given in a specific test or videos and visualisation of an analysis	Dashboard for one patient's data including his development in test results, and access to raw data, such as answers given in a specific test or videos and visualisation of the motion analysis

Analysis of results	Concept to interpret and codify patients/relatives answers of selected tests and to calculate test scores based on codified information. The Health Professional has to be able to modify or correct tests scores	Demonstration of functions to interpret and codify patients/relatives answers of selected tests; Ability to calculate test scores based on codified information. The Health Professional has to be able to modify or correct tests scores. For the mental and functional tests, the analysis and coding of the answers need to be shown, even if not in the final form. For the motion-related tests, the parameters extracted are gait speed, time spending during the tests, and so on. Here, state-of the art motion analysis tools should be used to start from.	Integration of these functions in the prototypes
Integration into clinical data management	Possibility to interface with clinical data systems in the overall concept	This version does not need to be able to be integrated into the overall clinical data management system	Prototypes able to be integrated into the overall clinical data management system
Data protection	Description of data protection concept and fulfilment of standards	Refined concept for data protection concept and fulfilment of standards and its integration into clinical data management systems	Proof of concept for integration into clinical data management systems including data protection and fulfilment of standards
Configuration			
Patient- specific configuration	Mock-up of system dialogues for selection of tests and definition of test sequences in form of flow charts6, handling of patient data	System dialogues for selection of tests, handling of patient data	Final version of system dialogues for selection of tests, handling of patient data
Integration of new/additional tests	Mock-up of a functionality to develop a new questionnaire-type tests.	Functionality of adding a new questionnaire. This should be doable by medical staff with help of system engineers.	Functionality of adding a new questionnaire. This should be doable by medical staff only.
Integration of new tests based on motion/video analysis	Description of concept. This type of new assessments need the help of system experts, but the specified system should have the possibility to add such things.	Proof-of concept in context with the prototype	Actual demonstration of adding a new analysis in context of the final evaluation
Calibration	Mention, if there is a need to calibrate the motion detection component	If calibration is needed, a first version of the calibration functionality (operated by system engineers) needs to be shown	If calibration is needed, the calibration functionality (operated by clinical staff) needs to be shown

[6] An example of such a test sequence is given in Annex I.

4.1.1 Functional specifications summary table

Functional specifications summary table	Doing test autonomously	Accompanied by Health Professional during tests
Selection, by health professionals, tests to be performed	X	X
Verbal interaction with patient/relative	X	
Ability to perform tests queries collecting information by autonomous interaction with patients/relatives (speech and touch screen)	X	
Ability to interpret and codify tests answers	X	X
Identification of test items the Health Professional is performing with patient/relatives		X
Coding test scores according to guidelines / configuration of the system	X	X
The Health Professionals must be allowed to modify tests scores	X	X
User-friendly interface to display tests results in a clear and understandable way (Dashboard-style with access to details)	X	X
Audio/video-recording and storage of raw and processed data during gait and balance tests	X	X
Audio/video-recording and storage of raw and processed data during other tests, like mental tests	X	

5 Use cases and expected demonstrable outcome

This use case will be a typical example of a test to be performed when evaluating the prototypes at the different phases of the development process.

Dr Fernández, geriatrist, receives a request from Doctor Bonilla for cognitive assessment of Mister Charles Balot, an 85 year old male patient living alone who has three children living far away from him. During the last three months they have detected memory problems and changes in Mr Balot's behaviour like including irritability and verbal aggressiveness along with careless handling at home (neglected toilet, expired food, etc.). Mr Balot does not recognize memory deficits neither his needs for support and goes to the visit almost exclusively because of the insistence of the family and Doctor Bonilla. His daughter, Marie, accompanies him. The scheduled time for the assessment is 60 minutes.

Dr Fernández thinks that, due to the different point of view between the elderly and his relatives, it is important to gather information separately from both the patient and his relatives. Therefore, he plans the CGA process as follows:

1. Clinical assessment with patient and his daughter.
2. Functional evaluation: Barthel and Lawton tests separately answered by patient and daughter.

3. Mental evaluation (cognitive and behaviour): subjective assessment of the patient, MMSE and Yesavage tests.
4. Social evaluation: direct interview with both, patient and relative.

At the beginning of the assessment the doctor receives Mr. Balot and Marie. After the initial review of Mr Balot's health status, Doctor Fernández proposes Marie to go with the assistant robot to perform the Barthel and Lawton tests while he stays with Mr Balot asking him questions to build up a subjective impression on Mr Balot's awareness of his limitations.

Mr Balot and Marie agree with the proposal of Dr Fernández. During the interview Mr Balot denies having problems for self-care and behaviour changes affecting his personal relations. At the end, Dr Fernández asks Mr Balot's consent to interview Marie to get her impression on her father's behaviour and memory and invites Mr Balot to go with the robot to perform the MMSE, Barthel and Lawton tests. In addition, the Tinetti Gait and Balance tests are performed to get a full overview of the patient's status.

Finally, the three of them meet again to complete the social assessment.

Mr Balot's results are:

Type of Assessment	**Participants**	**Test**		**Total Score**	**Interpretation**
Functional Assessment	Patient-Robot	Barthel	Barthel 6 months ago	100	Autonomy for basic activities
			Barthel at present	100	
		Lawton	Lawton 6 months ago	4	Autonomy for instrumental activities except transport
			Lawton at present	4	
	Relative-Robot	Barthel	Barthel 6 months ago	100	Patients' independence to perform basic activities
			Barthel at present	100	
		Lawton	Lawton 6 months ago	4	Patient's impairment for public transport use. But Patient's capability to phone and manage money, medication and shopping.
			Lawton at present	1	
Mental Assessment	Patient-Robot	MMSE		16	Probable cognitive impairment
	Patient-Robot	Yesavage		6	Probable mood disorder

After reviewing these results, Dr Fernández explains that Mr Balot has probably a cognitive problem. He recommends to perform additional tests (laboratory, neuroimaging and extended cognitive tests) to have a better diagnosis and to start treatment for the behaviour symptoms identified. At this stage, some issues are discussed such as the need for monitoring Mr Balot's medication and money management. Dr Fernández answers also to some questions of Mr Balot and Marie and a new appointment is scheduled to complete the assessment with the additional tests.

What are the benefits of using a technical solution?

Dr Fernández is partially relieved by the robotic solution during the 25 minutes needed to perform the 8 functional tests and has more time to focus on cognitive and behaviour assessments of Mr Balot.

- While Marie is doing functional tests with the robot, the Dr Fernández is able to maintain direct contact with Mr Balot to get an initial subjective impression of the patient's condition.
- While Mr Balot is doing functional tests with the robot, the Dr Fernández interviews Marie about his father's health status; including changes in behaviour and cognitive deficits.

So, interviews held separately shorten the total length of the process. By this means, Dr Fenández gets also better information by about Mr Balot's cognitive deficits and behaviour alterations; when the interviews are held jointly, relatives are cautious and are hesitant to comment serious behaviour disturbances to avoid later adverse reactions from the patient.

Interacting with the robot instead of a healthcare professional during the cognitive tests (MMSE and Yesavage), Mr Balot feels more confident during tests. Interaction with healthcare professionals causes him to feel examined and more nervous, anticipating the consequences the results could have on his autonomy.

The time reduction by using a robot during CGA gives Dr Fernández more time to devise the most adequate care plan including complementary tests, supervision of medicines, etc. This additional time will improve the adherence of the patient and his relatives to treatment. This plan is finally agreed with Mr Balot and Marie.

6 Business model

The demographic dynamics and the economic crisis require urgent actions to make the delivery of health and social services to the elderly more sustainable and to increase independent living at home for older people.

The research and development in the Robotics for Comprehensive Geriatric Assessment Challenge will focus on frail older people aged over 80 with the idea that a robotics solution introduced should help to improve the overall status of patients.

The target users of robotics technology for CGA solutions will be the Health Professionals, patients and their relatives during the CGA process.

6.1 Expected benefits of a robotic solution

6.1.1 Parallelization and time saving during the CGA process

CGA process duration depends on the setting where it is performed. On average, between 2 and 3 hours per patient are needed to complete the assessment.

Most of time is consumed to gather information in Phase 1 and Phase 2 (see 2.3.3. Phases of GCA) and, usually, the Healthcare professional lacks of enough remaining time to evaluate results and draw up the personalised care plan for the patient.

For instance, when CGA in performed in Ambulatory Care Units the process lasts only 60 minutes. In this settings time is a handicap and the health professional needs to hurry in Phase 1 and Phase 2 in order to complete the process; but many times the CGA process is not completed in one session and has to be continued in further sessions also in other hospital setting (usually Day Care Hospital Unit). All in all, in ambulatory care units the health professional has a lack of time to perform the process; especially for the final and most important phase, where the personalised care plan is organised.

On average, the execution of tests in the Multidimensional assessment (Phase 2) takes over 50% of the total time of the process while the individualised care (Phase 3) plan phase only lasts 11 % of the time.

A robotic device should be able to manage autonomously the execution of some tests and assist the Health Professionals during Phase 2, freeing up time for them to focus on more important activities of Phase 1 or Phase 3. Furthermore, this should also decrease health professionals' tiredness or fatigue perception as consequence of doing tests.

It should be expected a reduction of more than 30% of Health Professional's time to perform tests by using a robotic solution.

If the Health Professionals reduce the time spending with supporting devices and focus their attention on patients and their relatives during the CGA's process, and enable them to have more time to be spent for care planning decisions itself (the analytic and comprehensive final step of CGA) instead to spend very valuable time for just doing tests.

6.1.2 What are the costs today?

CGA it is not a rapid process. The initial assessment and care planning for a full CGA is likely to take at least 1.5 hours of professional time, plus the necessary time for care plan negotiation and documentation; that represents a total of 2.5 hours. But as on-going review are needed periodically, at least twice a year, hospitals need to increase efficiency of CGA process to be able to attend more patients and absorb the increasing demand.

Some actual costs in Catalonia are:

- The public health insurer (CatSalut) pays hospitals per CGA process performed:

Type of assessment	2012	2013
Mental Assessment	207,81 €	198,25 €
CGA – Not Mental Assessment	147,45 €	140,76 €

- Each Assessment unit may attend 5 patients per day and there are waiting lists of 2 or 3 months.

6.1.3 Track the improvement

Extensive research has shown that CGA in hospital increases independence (individuals are more likely to go home after this process compared to standard medical care) and reduces mortality. A recent Cochrane[7] review showed that those who underwent CGA on a ward had a 30% higher chance (Odd Ratio 1.31 Confidence Interval 1.15 – 1.49) of being alive and being in their own home at 6 months.

Existing studies state that it is highly likely that CGA in any setting will be an effective intervention for an elderly person identified as having frailty. In the community there may need to be local flexibility in terms of what constitutes an interdisciplinary team and how the medical input is provided – nevertheless, the principle stands. The resulting individualised care and support plan must include information for older people and their carers about how and when to seek further advice and possibly information which defines advance planning for end of life care.

6.1.4 Health insurances and customers interest

To attend the increasing demand, health insurers and hospitals need to improve efficiency of CGA processes and, additionally, they have to increase elder population service portfolio.

Improving cost efficiency in patient treatments is, and will be in the future, a big challenge. Robotics integrated in health service delivery may be part of the required solutions.

[7] Comprehensive geriatric assessment for older adults admitted to hospital (Review); Ellis G, Whitehead MA, O'Neill D, Langhorne P, Robinson D

6.2 Business opportunities for the R&D consortia

The successful applicants will have the opportunity to develop a detailed concept and a first prototype within the first 6 months. After this first stage of the PDTI R&D work, 2 out of the initially 3 selected consortia are selected to further develop the system during the remaining phases.

The main opportunities of the scheme are to develop a system with close interaction with the end users, to get known not only in a local environment to a single user, but also to show close-to-market prototypes on a European level to potential customers at the end of the activities. Potential business models include selling and maintaining the systems, specific services such as the implementation of more complex and clinic-specific tests, etc.

ANNEX I: EXAMPLES OF CGA TESTS AND TEST SEQUENCES

The most relevant tests are given in the following table in form of web links to documents and videos, and examples for currently used test sheets are given on the subsequent pages.

Tests	**Link**
Barthel Index	https://www.youtube.com/watch?v=03IsiYJSk0o
Lawton Index	http://downloads.lww.com/wolterskluwer_vitalstream_com/AJN/TRYTHIS_EP13_CH1_FINAL.wmv
Time Up and Go Test	https://www.youtube.com/watch?v=j77QUMPTnE0
MMSE test	http://videos.med.wisc.edu/videos/15378
Yesavage test (short form)	http://consultgerirn.org/resources/media/?vid_id=4200933#player_container
Other tests	http://consultgerirn.org/resources