Specifications after 1 month

	Description of requirements after Phase I	Description of implementation plan for Phase I (to be delivered after 1 month – by January 31, 2016)
General requirements		
Overall system	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.	ARNICA proposes to use Kompaï robot as a robotic device able to help with Comprehensive Geriatric Assessment. The robot has been already used to assist elderly people at home, institutions and hospital. The CGA module will be seen as an extension to robot's functions. 
Weight	Prototypes meeting the specification, the portability has to be demonstrated.	The weight of the robot is about 50Kg.

Power supply	The prototypes must be able to be operated both in battery mode and plugged as specified.	Kompaï is batteries powered for autonomous tasks and could be connected to standard 220/230VAC power supply through its charger.
Language interface	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.	Our multi-language (Spanish, English, French …) speech to text and text to speech uses natural language interface. Catalan is not available.
Touch-screen interaction	Full implementation of all dialogues 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.	Yes
Motion tracking	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.	Yes full implementation will include motion tracking already available on the Kompaï robot with associated motion analysis software and dashboard. The Get-Up and Go test will be solved by means of computer vision techniques. In fact, other tests which need to be completed during subsequent phases of the project, as the Tinetti balance and Tinetti gait tests (as described in the last pages of the Challenge description document) will be as well solved from a computer vision approach. The result will be a computer vision module that can be integrated in the whole ARNICA system In ARNICA we shall be using RGB-D information, that is, the combination of an RGB camera plus depth information about the scene being observed hence providing 3D information about the scene. Developments will be based upon the data received from popular Kinect camera (last commercialized version). This camera has been selected among other RGB-D cameras mainly because of two reasons: first, its low price; second, since it allows a rapid design and prototyping phase to be carried on thanks to existing SDK libraries (for instance the one provided by Microsoft).

		However, the functionalities developed for ARNICA will not be limited to the use of this sensor or a given SDK, as our algorithms will use a general point-cloud data point of view, and at the end of the project will not depend on proprietary SDKs (as the Microsoft one) but on own generated code in C++ (and using open-source libraries as the well-known Open-CV, or point cloud, PCL, libraries) which will be platform independent. In outlining the specifications for the Get-Up & Go test, and in general for the computer vision module inside ARNICA solution, we would like to distinguish two levels of functionalities: - A partially functional module, provided as a mock-up of the complete system in order to answer the requirements on the first Phase of the project. - A complete computer vision module with enhanced functionalities for Phases 2 and 3 of the project.
Mobility		
Platform's ability in terms of person following, face tracking, and similar advanced features	Implementation of patient motion tracking functions on sensors used for activity analysis.	During the first phase patient detection and tracking by using depth camera information will be implemented. Enhanced patient detection and tracking allowing for more than one person to be tracked, since there exists a high probability that patients with motion difficulties are accompanied by medical staff during motion tests will be implemented during phase 2.
Actual testing		
Dialogue (questionnaire)-based tests	Implementation of the following dialogue- based tests. Ideally: Functional tests: Barthel and Lawton tests. Mental tests: Pfeiffer test, MMSE test, and Yesavage test.	The implementation of Bathel index with be implemented in the first phase using autonomous execution through vocal dialogue between the robot and patient. The other will be implemented in the second phase.
Tests based on motion analysis	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.	For this first phase we will only consider the Get-Up & Go test, as described in previous section, and provide the following functionalities: - Capturing video from mobility tests and storing it allowing to record patients' performance. We will use an understandable filename convention including the reference for the patient

being evaluated, the name of the performed test, and the date of the test (year_month_day) so in later phases is easy to perform automatic comparison of videos. The video will be provided using open-source implementations of media formats (so called video codecs) as for instance OpenH264 or Xvid so to avoid possible fees due to registered patents.

- Visualization of videos (real-time and previously recorded) in a user-friendly way (dashboard style)
- A calibration algorithm for the used sensor in the proposed scenario (to be operated by system engineers at this point)
- Patient detection and tracking by using depth camera information
- Determination of the time the patient needs to complete the Get Up & Go test
- Determination of an approximate measure of the step length of the patient.

For the first phase, and with the aim of demonstrating the potentiality of the computer vision module, we will assume the following hypothesis:

- The Get Up & Go test will be performed in an office with provided measurements in page 8 of the document containing the evaluation criteria, that is an office of 4x6m.
- The visual sensor will be at a static position, either on the robot (stopped), on a table, or on a tripod. A minimum height of 1.5m for the sensor is required to cover the room space given its FOV characteristics.
- The Get Up & Go test will be performed with only one person, that is, the person performing the test will not have aid of another, since at this point we will be detecting and tracking only one person.
- No occlusions will exist between the sensor and the observed person.

In a very brief summary (more details provided in the Technical approach section) our technical approach for the first phase will be:

		- Vision sensor calibration. - Foreground extraction. - Obtain time and step length parameters by computing the position and velocity of the centroid of the 3D moving data points.
Audio/Video recording	Full recording capability integrated.	Capturing video from mobility tests and storing it allowing to record patients' performance. We will use an understandable filename convention including the reference for the patient being evaluated, the name of the performed test, and the date of the test (year_month_day) so in later phases is easy to perform automatic comparison of videos. The video will be provided using open-source implementations of media formats (so called video codecs) as for instance OpenH264 or Xvid so to avoid possible fees due to registered patents.
Evaluation and data management		
Patient-specific view	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 visualization of the motion analysis.	We propose to use Amazon Web Services (AWS) to store and manage robot data and personal data related to CGA module (raw data and analysis of results). As the data will be anonymised for their protection a dashboard will be integrated to display raw data, analysis of results and association of these data to the specific patient. Comparison with previous data and results will be also available on the dashboard.
Analysis of results	Integration of these functions in the prototypes.	Yes analysis of results will be implemented in the prototypes
Integration into clinical data management	Prototypes able to be integrated into the overall clinical data management system.	Data management is ensured by a standard whether for anonymization, storage and treatment allowing them to be part of the global clinical data management system.

Data protection	Proof of concept for integration into clinical data management systems including data protection and fulfilment of standards.	Patient data are subject to protection and privacy with respect to their transfer, storage and processing. Data protection plays a significant role to reduce or even inhibit the processing of sensitive data (Art. 8 of Directive 95/46/EC), which encompasses personal health data. The processing of such data is prohibited also by the Convention for the Protection of Human Rights and Fundamental Freedoms. Considering the importance of individual health data to appropriate medical treatment of a patient, the Directive 95/46/EC [95-46EC16] itself provides exemption to the general prohibition of their processing in the Articles 8(2) and (3), which allows derogating from Art. 8(1) if: • the patient as 'data subject' has explicitly, in the meaning of freely, specifically and in an informed manner given his consent; • the processing can be justified by being in the vital interest of the data subject, for example for life-saving treatment and when the person is not able to express his intention. The Article 29 Working Party illustrates this legal ground as follows: "assume a data subject has lost consciousness after an accident and cannot give his consent to the necessary disclosure of known allergies. In the context of EHR systems this provision would allow access to information stored in the EHR to a health professional in order to retrieve details on known allergies of the data subject as they might prove decisive for the chosen course of treatment; and • if they are processed by health professionals, subject to professional (medical) secrecy, for the purpose of preventive medicine, medical diagnoses or the provision of care and treatment or the management thereof. Data privacy refers to the evolving relationship between technology and the legal right to, and public expectation of privacy in the collection and sharing of data. Privacy problems exist wherever uniquely identifiable data relating to a person or persons are collected and stored, in digital form or otherwise. Improper or non-existent disclosure control can be the root cause for privacy issues.

		Some big data providers start proposing services for personal data (storage, treatment …) with robust security standards. For example Amazon Web Services (AWS) Cloud Compliance enables customers to understand the robust controls in place at AWS to maintain security and data protection in the cloud. As systems are built on top of AWS cloud infrastructure, compliance responsibilities will be shared. By tying together governance-focused, audit-friendly service features with applicable compliance or audit standards, AWS Compliance enablers build on traditional programs; helping customers to establish and operate in an AWS security control environment. With regards to Directive 95/46/EC the Luxembourg Data Protection Authority (CNPD), acting as lead authority, in cooperation with other concerned European Data Protection Authorities pursuant to the Working Document 226, adopted by the Article 29 Working Party, have analysed Amazon Web Services, Inc.'s (AWS) "Data Processing Addendum" and its Annex 2 "Standard Contractual Clauses" which incorporates Commission Decision 2010/87/EU. The aim of the review by the Data Protection Authorities (DPAs) was to evaluate whether these documents strictly meet the requirements on international data transfers contained in the Standard Contractual Clauses of the Commission Decision 2010/87/EU (the so-called "controller-to-processor" clauses). On 6 March 2015, the CNPD issued a letter, confirming that the Data Processing Addendum of AWS was in line with the Standard Contractual Clauses of Commission Decision 2010/87/EU and acknowledging that, by using the "Data Processing Addendum" together with its annexes, AWS will make sufficient contractual commitments to provide a legal framework to its international data flows, in accordance with Article 26 of Directive 95/46/EC. Furthermore, the Luxembourgish DPA thanked AWS for the constructive collaboration that has led to these positive conclusions. Furthermore AWS data centres are built in clusters in various countries around the world. We refer to each of data centre clusters in a given country as a "Region." Customers have access to eleven

		AWS Regions around the globe, including two Regions in the EU – Ireland (Dublin) and Germany (Frankfurt). Customers can choose to use one Region, all Regions or any combination of Regions. This allows compliance with specific directives for each country to respect this data. In privacy preserving data publishing, in order to prevent privacy attacks, data should be anonymized properly before it is released. Anonymization methods should take into account the privacy models of the data and the utility of the data. Anonymization techniques have been the focus of intense research in the last few years. An important requirement for such techniques is to ensure anonymization of data while at the same time minimizing the information loss resulting from data modifications. From the literature there are two categories of anonymization methods: • Clustering-based approaches: anonymity model assumes that person-specific data are stored in a table (or a relation) of columns (or attributes) and rows (or records). The process of anonymizing such a table starts with removing all the explicit identifiers, such as name and SSN, from the table. However, even though a table is free of explicit identifiers, some of the remaining attributes in combination could be specific enough to identify individuals if the values are already known to the public. The main objective of this method is thus to transform a table so that no one can make high-probability associations between records in the table and the corresponding entities. • Graph modification approaches: A graph modification method anonymizes a graph by modifying (that is, inserting and/or deleting) edges and vertices in a graph. The modification can be conducted in three ways and correspondingly there are three sub-categories of the methods. The optimization approaches try to make up an optimal configuration and modify the graph accordingly. The randomized graph modification approaches conduct perturbation. Last, the greedy graph modification approaches greedily introduce modification to meet the privacy preservation requirement and optimize the data utility objectives.

		In this first phase we will implement some of these methods on the mock-up for a possible benchmark in the following phases.
Configuration		
Patient- specific configuration	Final version of system dialogues for selection of tests, handling of patient data.	The CGA module user interface will be integrated in the actual Robot HMI you can watch here: https://www.youtube.com/watch?v=VcmHkXgVxfs. Specific screens will be designed to provide an optimal viewing and interaction with personal care for CGA module.
Integration of new/additional tests	Functionality of adding a new questionnaire. This should be doable by medical staff only.	A standard questionnaire may be integrated into the solution by personnel care. This will require the definition of the questionnaire and associated answers in a file accessible by password. The questionnaire is automatically added to the list of questionnaires to choose via the HMI.
Integration of new tests based on motion/video analysis	Actual demonstration of adding a new analysis in context of the final evaluation.	For subsequent phases we will consider the whole requirements in the challenge and enhance and complete the mock-up developed in Phase 1 with the following additional functionalities: - Automatic comparison of videos gathered for a patient for a given test on different sessions. The system will hence offer the ability to record and evaluate patients' performance at the beginning and at the end of a rehabilitation process. - Enhanced visualization of videos with gait parameter information impressed on the video sequence in real-time. This will provide professionals with a global patient performance vision. - Text-based reporting about the patients' performance in motion analysis tests for fast and easy results communication among professionals. This tool offers the ability to calculate tests scores based on video codified information and will allow health professionals to modify or correct obtained tests scores. - An automatic calibration tool for the vision system, so professionals do not need to care about this procedure. - Enhanced patient detection and tracking allowing for more

		than one person to be tracked, since there exists a high probability that patients with motion difficulties are accompanied by medical staff during motion tests. - Complete set of motion analysis tests, including Get-Up & Go, and Tinetti balance and gait tests. - Additional body motion analysis providing information (position and velocity) about differentiated parts of the body: upper part, arms, head, lower part, legs and feet. This will be solved by fitting RGB and depth data to a simple skeleton model. - Scalable and platform independent architecture for future added functionalities such as face detection and recognition, people detection and tracking from a moving robot, or increasing robustness by multiple camera views. For Phases 2 and 3, the following hypothesis will be considered: - Motion analysis tests will be performed with the vision sensor at a static position, either on the robot (stopped), on a table or on a tripod. - More than one people detection and tracking will be possible, and partial occlusions of the patients' body will be handled. **Technical solution proposed:** For the ARNICA project we will adopt a marker-less solution in which there are no attached markers on the body of the studied person. More concretely, our technical solution is proposed as follows: - Calibration. A first step of calibration will be performed so to derive intrinsic and extrinsic parameters of both cameras and to be sure that depth data is calibrated against RGB data. Also, a calibration of the depth measurements obtained will be performed. The calibration will be performed by using a common calibration method by means of placing a printed checkerboard calibration pattern at different distances and orientations with respect the sensor. For the first phase, this calibration will be performed manually by engineer staff, whilst for second and third phases we will develop an

		automatic calibration method for the vision sensor. - Foreground extraction. For the first phase we will perform a foreground extraction (performed on the depth images) by using a simple background subtraction algorithm. Basically, we will capture a set of images and compute maximum and minimum depth values for each pixel to form a background model. Then, each time a new frame arrives we will consider foreground those pixels whose raw depth values lies outside the learnt background range. Furthermore, we will apply noise reduction techniques to the identified foreground pixels (filtering and smoothing) to finally obtain a 3D point cloud representation of the person being observed. - Single person tracking. Based on the obtained 3D point cloud representing the observed person, we will obtain from frame to frame the moving pixels and hence perform a tracking of a single person. - Simple step length determination. For the first phase we will derive gait parameters based on a very simple model. Based on the single person tracking performed, we will derive the centroid of the 3D point cloud and then compute its position and velocity by projecting the centroid onto the ground plane and calculating a best fit line to represent the direction of travel for the walking sequence. - Multiple people tracking. This is necessary for Phases 2 and 3 since it is possible that a health professional needs to closely accompany a patient to perform motion analysis tests and hence eliminate the possibility of a patient to fall down. We would like to maximise robustness, so our approach will be to fuse the information provided by different algorithms based on RGB-D information, some of them known to work from a mobile platform. Although at this point this is still to be further evaluated we shall consider: image based pedestrian detector, upper body detector, face detector, skin detector, depth-based shape detectors and motion detector. The fusion scheme will be probably based on a Monte Carlo particle filtering approach. - Complete body motion analysis. We will provide enhanced information about the patients' body motion, including

		balance, gait and different body parts motion. Based on the results of previous people detection and tracking we will obtain the silhouette of the persons of interest, project it onto a discretized volume space and fit a simple skeleton model to the intersection formed by the projection of the silhouette with the discretized volume space. For ARNICA application we propose a very simple skeleton model with head, arms, torso, and legs sections (although we shall study as well the inclusion of elbows and knees). Our solution will be completely implemented in C++ suing open-source libraries such as OpenCV or Point Cloud Library, and it will be platform independent so it is easily installed in different computers regardless its operating system. Moreover it will designed modular and scalable from the beginning so new modules can be easily added in the future, as face detection and recognition abilities.
Calibration	If calibration is needed, the calibration functionality (operated by clinical staff) needs to be shown.	For the first phase a manual calibration of the computer vision module (motion analysis) will be available. For Phases 2 and 3 this calibration step will be automatic.