ROBOTS IN ASSISTED
LIVING ENVIRONMENTS

UNOBTRUSIVE, EFFICIENT, RELIABLE AND MODULAR SOLUTIONS FOR INDEPENDENT AGEING

Research Innovation Action

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Abstract

This report plans the *final round summative phase of pilots* that will test the final integrated RADIO prototype, including the robotic platform, smart home functionalities and the final prototype of RADIO GUI and establishes the procedures for collecting questionnaires, RADIO output and ground truth observations for estimating the usability and efficacy of the system.

History and Contributors

Ver	Date	Description	Contributors
00	04 Oct 2017	First draft, based on D6.3. Updated dependencies. Sections added: 2.2.5/2.2.6	NCSR-D
01	04 Oct 2017	Updated description of FZ pilot setting in Section 2.2.2 (Paragraphs 3/4/5). BLE description in Section 3.5. BLE "Find my keys functionality" described in Section 2.2.5.	TWG
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04	23 Oct 2017	New paragraph *Interaction with the RADIO robot and Smart Home via the RADIO GUI in* Section 2.1.3	NCSR-D
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Fin	7 Dec 2017	Final preparations and submission.	NCSR-D

Executive Summary

This report plans the *second round of the summative phase of pilots* that will test the final integrated RADIO prototype. More specifically, this report details the number of the participants and how long they will work with the consortium in the final round of the summative phase of pilots (M31-M33) both at *private residences outside of any medical care institutions* (FZ) and at the *FHAG Geriatric Centre*. This report describes the scenarios of both pilots. It also describes the study design, the procedures for collecting questionnaires, RADIO output and ground truth observations for estimating the usability and efficacy of the system. This report also appends the updated data recording forms to be filled by research assistants and nurses during the pilot studies, as well as the manual provided to them for operating the robot and recording the ADLs.

Abbreviations and Acronyms

ADL	Activities of Daily Living
IADL	Instrumental Activities of Daily Living
interRAI	International collaborative to improve the quality of life of vulnerable persons through a seamless comprehensive assessment system. Cf. http://www.interrai.org
interRAI HC	The *interRAI* Home Care Assessment System
interRAI LTCF	The *interRAI* Long-Term Care Facilities Assessment System
MMSE	Mini Mental State Examination
PIADS	Psychosocial Impact of Assistive Devices Scale
SUS	System Usability Scale
ASQ	After-Scenario Questionnaire
SCRSA	Self-Contained RADIO Smart Apartment, the RADIO installation at FHAG.
RA	Research Assistant

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1 INTRODUCTION

1.1 Purpose and Scope

RADIO presents a domestic assistant and home automation profile to the end-user, which most importantly acts as an unobtrusive health monitoring system. RADIO's main objective is an unobtrusive monitoring system whose equipment is an obvious and accepted part of the user's daily life, by adopting a smart home/assistant robot approach, where the sensing equipment actively strives to be obvious and closely located to the user; that is, we propose that robot companions and assistants are used to collect the data needed for medical monitoring.

RADIO system will provide a pool of ICT based in-home services that will be offered to elderly users that live at home to improve time spent autonomously at home. Although the RADIO system is primarily presenting a domestic assistant and home automation profile, it is also acting as an unobtrusive health monitoring system and as an instrument for medical evaluation. It will ensure the timely availability of the patients' clinical and behavioral data to allow timely prognosis and clinical actions. Through its direct involvement in end-users' daily activities, RADIO observes *activities of daily life* and *mood*. These observations are used to establish patterns and identify deviations. Moreover, RADIO empowers new care service provisioning models based on the remote supervision of the elderly/patients from the medical experts and/or health professionals or caregivers. It deals with the extraction/derivation of reinforced medical knowledge associated with symptoms, good practices, treatments and personalized patterns of treatment for elderly users.

The purpose of this document is to plan the execution of the *final round* of s*ummative phase* pilot studies (M31-M33). The scope of the study is to pilot the final integrated RADIO prototype (D5.9, M30) at **FHAG** *Geriatric Centre premises* and *private residences outside of any medical care institutions* (**FZ** clients). The objectives of these pilots are to:

1. To evaluate the usability of the system for the primary and secondary users
2. To evaluate the system's fitness for its medical purpose
3. To evaluate the ease of installation of the RADIO system.

Specifically, this report focuses on planning the details, the profile and number of pilot participants. Moreover, it describes the prototype deployment and pilot study execution method. This report also appends the caregiver's manual for FHAG and FZ pilots and the technical installation manual.

1.2 Approach

RADIO pilot studies have been designed in three phases:

1. Formative phase; first pilot at FSL (D6.1/D6.5/D6.9)
2. Intermediate phase; second pilot of RADIO components at FSL (D6.2/D6.6/D6.10/D6.13)
3. Summative phase; final RADIO pilots.

The Summative phase includes **two rounds** of pilots, one during M25- M27 and one during M31-M33. Both rounds include pilots at FHAG premises and at the private homes of FZ clients who have volunteered to participate. The objectives of these pilots are (a) to validate the prototype of the overall RADIO system; and (b) to provide data for the final, summative user evaluation report and medical evaluation report. This deliverable plans the **second round** of summative piloting phase.

The steps leading up to carrying out the second round of pilot are described in the Tables below (described separately for FHAG and FZ studies).

Table 1. Time plan for FHAG pilot study deployment preparation

NCSR-D, TWG, RUB, ROBOTNIK, S&C, FHAG	Pilot preparation meeting and technical meeting.	4-5-6 Oct 2017
NCSR-D, ROBOTNIK	Testing updated final RADIO prototype at ROBOTNIK premises	9 - 13 Oct 2017
FHAG	Running preliminary pilot study, testing the final robot prototype and the pilot procedure	16 -27 Oct 2017
NCSR-D, FHAG	Working on solving several technical issues.	30 Oct - 3 Nov 2017
ROBTNIK, FHAG	Installation of robotic shell.	7 Nov 2017
FHAG	Running final pilot study.	November – December 2017

Table 2.Time plan for FZ pilot study deployment preparation

NCSR-D, TWG, FZ	Pilot preparation meeting at TWG premises. Testing updated final RADIO prototype.	30 Oct 2017
TWG, FZ	Training of FZ caregiver at TWG premises	1 - 3 Nov 2017
NCSR-D, TWG	Setting up final pilot details for private premises.	4 - 8 Nov 2017
TWG, FZ	Running preliminary pilot study, testing the final robot prototype and the pilot procedure at private premises.	13-24 Nov 2017
FZ	Running final pilot study.	December 2017-February 2018

NCSR-D, TWG, ROBOTNIK and S&C will support the pilot with personnel on the phone/email (throughout the whole pilot).

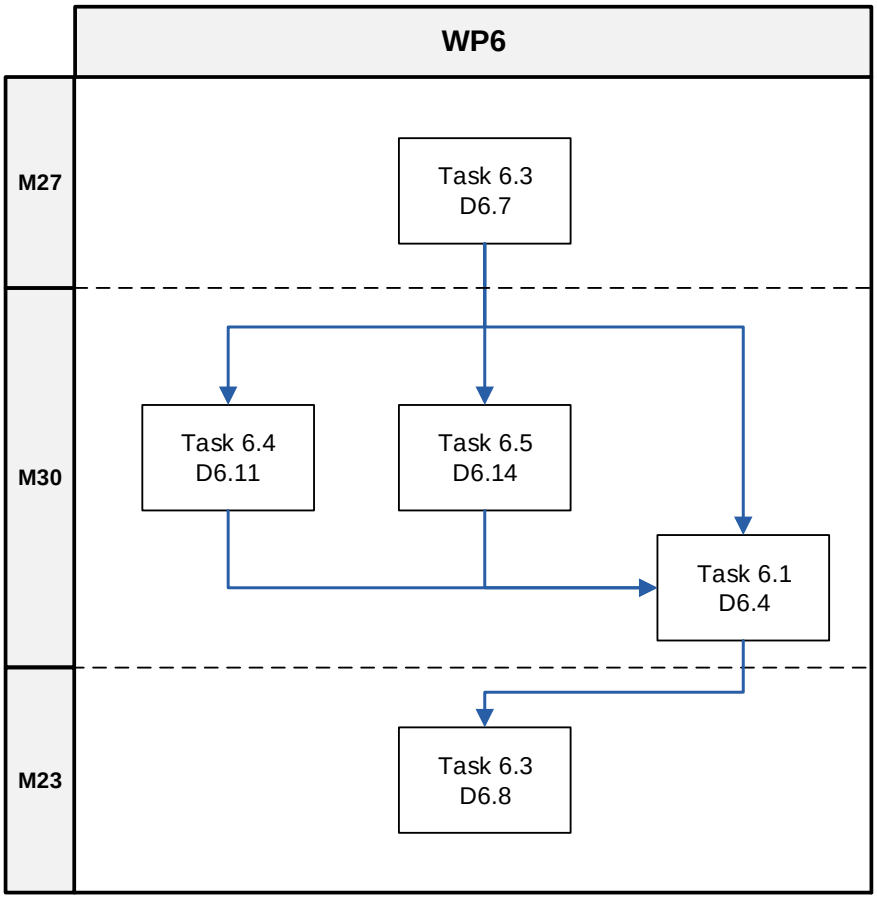

Figure 1. Dependencies between this deliverable and other deliverables.

1.3 Relation to other Work Packages and Deliverables

This deliverable is prepared within Task 6.1 *Piloting plan development* and it describes the pilot planning of the second round of summative phase of the pilots and it takes into account the outcomes of the first round of summative phase pilot trials as reported in *D6.7 Pilot report I* and *evaluated in D6.11 User evaluation report III* and *D6.14 Medical evaluation report II.*

This report plans the *second round of trials of the summative phase* study that will be carried out at FHAG premises and at the private homes of FZ's clients in the context of *Task 6.3 Pilot deployment and execution (M31-M33)* to produce D6.8 *Pilot report III (M33).*

These dependencies and interactions are also graphically depicted in Figure 1.

2 SUMMATIVE PHASE PILOTS: MATERIALS AND METHODS

The summative phase is dedicated to the evaluation of the usability and fitness of purpose of both the first and final ***integrated RADIO prototype***. These will be tested during M25-M27 and M31-M33, accordingly. Particularly this reports describes the details related to the final round of pilot studies during M31-33 at both FHAG premises and at private homes of FZ's clients.

2.1 Pilots at FHAG

2.1.1 Participants

Sixteen (16) participants will be involved in the first round of the summative phase of pilots, starting from the 16th of October. Each participant will work **3 days** with the consortium.

Participants will be recruited from Day Hospital and Adolfo Montanya Nursing Home. For the pilot study all subjects will give written informed consent for participation. Two weeks before the onset of the study, each potential candidate will be invited by a Research Assistant (RA) to a half an hour appointment that will take place at the Self-Contained RADIO Smart Apartment (SCRSA) to be informed about the purpose of the study and discuss any potential issues. At this stage, following detailed information, the participant will give signed consent to precede the study.

Participants will be selected based on the inclusion and exclusion criteria as described in *D2.1 Early detection methods & relevant system requirements I (*see *Section 2.4.2*). In reference to the exclusion criterion related to the ability to operate the RADIO system, if a participant is unable to operate the RADIO system during 3 training sessions he will be excluded.

2.1.2 Description of pilot setting at FHAG premises

The test will take place inside the *Self-Contained RADIO Smart Apartment* (SCRSA) in Fundació Hospital Asil de Granollers. SCRSA is placed on third floor of the Adolfo Montanya (AM) Geriatric Centre (Figure 2). The S&C ***Smart Home services*** and the related ADLs (when applicable) are listed in Table 3. The sensors related to each service are detailed in Section 3.5.

Table 3. FHAG Smart Home Services and related ADLs

Services	***Related ADLs***
Security (Flood, smoke, movement and intrusion detection)	**Going out of the house** (related to movement detection)
Control: To turn on/off equipment & scheduling (Lights, air conditioning, blinds, electric appliances)	**TV watching** (related to control of TV set)
Consumption: Information on electricity consumption and scheduling (Room electric consumption, Cooker, electric appliances)	**Meal preparation** (related to use of electric appliances)
Comfort: Knowledge about comfort values at home /Other smart home automations (Motion, Temperature, Light, Humidity, Vibration, UV)	N/A

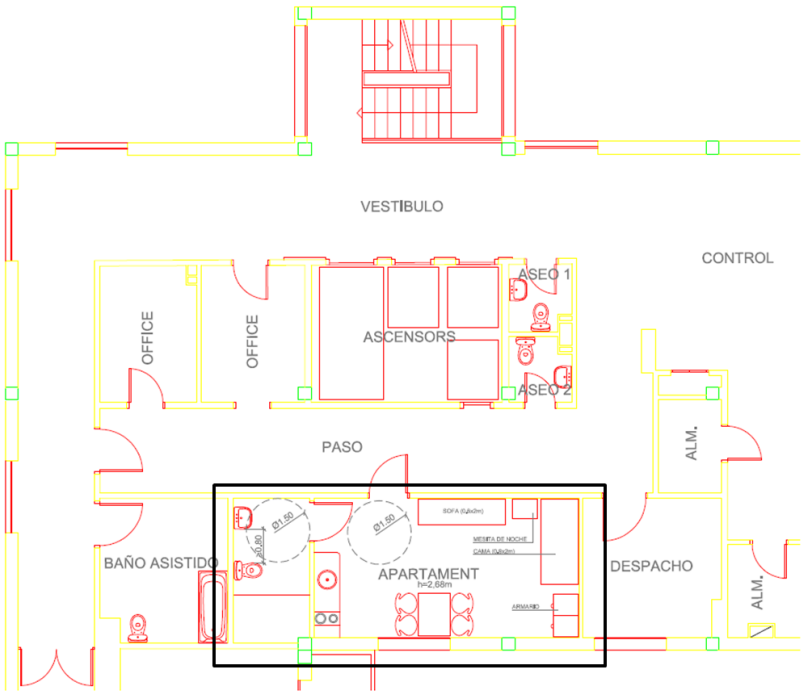

Figure 2. Floor map of the 3rd floor of the Adolfo Montañá Geriatric Centre.

The black rectangle marks the SCRSA with bedroom, dining space, kitchen and bathroom facilities

Figure 3. RADIO robot and piloting premises at Adolfo Montañá Geriatric Centre.

Picture A shows the final RADO robot prototype, picture B show part of the Self-Contained RADIO Smart Apartment (SCRSA); picture C shows the bathroom in the SCRSA; and picture D shows the outpatients doctor visit room .

The ***robot functionality*** in the FHAG piloting scenario will be to use the robot to be guided to the outpatients visit room. Participants will use the GUI to ask the robot to guide them to their doctor's room.

2.1.3 Smart Nursing Home Scenario Description

Illustrative Scenario

Mrs. Josefa Pérez is an 80 years old lady with chronic medical conditions, without serious functional impairment who was admitted to our Nursing Home 2 years ago because she became widow, felt alone and was concerned about her performance managing on her own in the community (showed difficulties on managing finances and her medication).

Two weeks before the onset of the study, our Research Assistant (RA) will invite her to participate. A half an hour appointment will take place at SCRSA premises informing and discussing the purpose of it. At this stage, following detailed information, consent forms (see Appendices I and II in D6.3) will be signed by the participant.

The first day of the study will be dedicated to assessment and training. *On the day of the study* the RA will pick up Mrs JP from her bedroom at room 21 on AM Nursing Home and perform the standardized Comprehensive Geriatric Assessment (CGA) using interRAI LTCF form (see D2.1).

Following CGA the RA will introduce interfaces, equipment and other facilities of the Smart Nursing Home as well as relevant considerations about safety and alarms. The SCRSA is connected 24 hours to the nursing central station. The RA will work with the patient in order to become familiar with the technology and up to three runs of information and practice with the Graphic User Interface will be offered before deciding that the patient is able to participate in the study. The RA will spend enough time to train the patient with the functionalities similar to what described in D6.2/Section 2.2.2 Training description. After the baseline assessment and training the scheduled program will consist of 2 days at the SCRSA (without overnight stay), completing three days all together for each participant at the FHAG pilot study.

Following the training day, the study will start with data collection on human activity patterns with the RADIO system as it is presented in Table 4. We will work with 3 sub-scenarios at morning, afternoon and dinner times where basic (bed transfer, chair transfer, 4 meters walk) and instrumental (pill intake, meal preparation) activities will take place. Moreover, each participant will be given the opportunity to use smart home's functionalities. Each sub-scenario has its own description and it is characterized by specific activities that will happen in these periods of time. Health Care personnel will be present during specific periods of time (sub-scenarios: breakfast, lunch and dinner time) to make the ground truth assessment.

The study finishes on Day 3 with the fulfilment of usability, satisfaction and quality of life questionnaires and in-depth interview about potential obtrusiveness of the technology for qualitative analysis.

Standard schedule

Table 4. Standard schedule for FHAG pilot study scenario.

Day	Sub scenario	Schedule of events
D1 Training Day	***Phase Baseline: Assessment 0***. (11:00 – 12:30)	• Arranged admission at 11:00 hours/Reception • Comprehensive Geriatric Assessment (CGA) by health care personnel. • Information and training with RADIO system (up to three runs) • Use of GUI: training • Initial ADLs recording: Bed transfer, Armchair transfer, Pill intake, 4 meters walk inside.
D2 Study Day	***Phase Baseline: Assessment I*** (11:00-12:30)	• Start of the study • ADLs recording: Bed transfer, Armchair transfer, Pill intake, 4 meters walk inside.
	Phase II (Lunch) (13:30 – 15:00)	• Pill intake -Lunch time medication • Chair transfer -Lunch dining room • Lunch ADL recording: 4 meters walk inside • Armchair transfer, 4 meters walk inside, Armchair transfer, • Bed transfer- Lunch nap • Use of GUI for TV watching (activation of TV set and TV watching event detection) • Use of GUI for: Comfort and safety (switching on/off TV set, blinds down, lights off, arming safety alarm) • Going out
	Phase III (Dinner) (19:00 – 20:30)	• Dinner time medication (Pill intake) • ADLs recording: Chair transfer, 4 meters walk inside. • Meal preparation • Use of GUI: turning on/off the TV
D3 Study Day	***Phase I (Breakfast)*** (08:00 – 09:30)	• Final ADLs recording: Bed transfer, Armchair transfer, Pill intake, 4 meters walk inside. • Meal preparation: Breakfast
	Phase I (Outpatient's Visit) (09:30 – 10:00)	• Use of GUI for going out to the doctor's appointment: the user uses the GUI to ask the robot to guide him to the doctor's outpatients visits. • 4-meter walking test outside the RADIO Smart Apartment (towards the OP) • Use of the GUI for coming back to the apartment: the user activates the GUI to ask the robot to guide him back to the apartment. • 4-meter walking test coming from OP • End of the test. Use of GUI for deactivation (switching on/off TV set, blinds down, lights off) • Final assessments and usability, QoL and obtrusiveness evaluation

All scenarios presented above are going to be repeated twice (see Appendix I).

Interaction with the RADIO robot and Smart Home via the RADIO GUI

During the pilot study the user interacts with the RADIO system via the RADIO GUI to complete the following tasks:

- To turn the TV on and off
- To control the blinds of the room
- To turn the bedroom and kitchen lights on and off
- To ask the robot to guide him/her in the doctor's room and back to the SCRSA.

Introduction to the RADIO robot and Smart Home

The following description is used before starting the pilot study to introduce the participants to the RADIO system.

> *What is the RADIO environment?*
>
> *RADIO environment is a Smart Home equipped with a robot. You can use Smart Home automations to control the house through a tablet, for example to regulate the temperature or turn on and off the lights. The robot can support you in doing things like for example visiting the doctor. At the same time the robot can collect information that clinical staff can use to judge whether you can safely live alone, such your ability to walk and get in and out of chairs and beds and your ability to regularly take medication.*
>
> *In the pilot study, the RA/nurse will ask you to complete some of these activities to test the research prototype built during the project. However, in the final commercial product these activities would not be recorded in fixed session but as part of your interaction with a more complete robot that can freely move around to assist you with various daily chores. What we are testing is the idea that a future robot that is a general assistant can also be used for this health monitoring and that a house-wide permanent camera surveillance is not necessary, at least for medical purposes.*

2.1.4 Evaluation Methods

The objectives of the study have in some way hierarchical priorities: first of all, the accuracy of the RADIO platform to measure activities of daily living, then to assess usability of the system and finally to analyse if there is any impact on self-perceived quality of life. So, we will have different statistical analyses according each of these objectives.

Evaluation of functional ADL

Functional status will be assessed with the interRAI LTCF instrument at the beginning of the study. Section G regarding physical function, in particular, will be measured also at the end of the study. The Folstein's MMSE will be performed to all participants as part of the comprehensive geriatric assessment.

Usability measures

RADIO overall usability will be measured using SUS, ASQ and PIADS questionnaires. Details regarding the questionnaires as well as statistical methodology are provided in Section 2.3 of *D6.2 Piloting Plan II*. Here we provide some further clarifications regarding the introductory questions to each questionnaire.

- **System Usability Scale (SUS)**

  "Your experience with the RADIO robot and smart home is based on a system that is a research prototype. To what extend do you agree or disagree with the following statements?"

  Then, the statements of the SUS are posed, where 'website' is substituted with 'RADIO system'

- **Psychological Impact of Assistive Device Scale (PIADS)**

  "Your experience with the RADIO robot and smart home is based on a system that is a research prototype. how the RADIO system did affect you?"

  Then, the questions of the PIADS are posed.

- **After Scenario Questionnaire (ASQ)**

Two ASQs are used for two scenarios; one is targeted to the interaction with the robot and the other to the interaction with the Smart Home functionalities. The introductory notes for each scenario and the statements posed following these are presented below.

ASQ 1

*"Based on you experience with the **RADIO robot**, to what extend do you agree or disagree with the following statements:"*

1. Overall, I am satisfied with the ease of completing this task.
2. Overall, I am satisfied with the amount of time it took to complete this task.
3. Overall, I am satisfied with the support information (training, explanations by RA, documentation, practical demonstration) when completing this task.

ASQ 2

*"Based on you experience with the **RADIO smart home**, to what extend do you agree or disagree with the following statements:"*

1. Overall, I am satisfied with the ease of completing this task.
2. Overall, I am satisfied with the amount of time it took to complete this task.
3. Overall, I am satisfied with the support information (training, explanations by RA, documentation, practical demonstration) when completing this task.

Improving Quality of Life

The impact of the RADIO ecosystem will be tested on Nursing Home (NH) participants. The self-reported Quality of Life instrument for Nursing Home Residents has up to 50 items grouped in 10 domains including privacy, food/meal, safety/ security, comfort, making daily decisions, respect, responsive staff, staff-resident bonding, activity option and personal relationship. These domains are very important in LTCF. There are two levels of scores; those domains specific and an overall aggregate score. In order to assess the impact of the RADIO ecosystem on patient's quality of life we will a before and after "intervention" assessment comparing these two measurements. We will consider non parametric tests due to small size of samples ($n < 30$). Descriptive statistics for central tendency and dispersion will be given with median plus interquartile and Wilcoxon test for paired data when testing mean differences.

In addition to usability and QoL assessment, each participant goes through a custom made semi-structured interview regarding **obtrusiveness** based on Hensel's dimensions (*see* Appendix VII/D6.3). Data will be transcribed to Atlas.ti[(4)] software to perform qualitative data analysis and generate hypothesis on patient's perceptions of obtrusiveness.

Qualitative analysis uses analytical categories to describe and explain social phenomena. All data relevant to each Hensel's dimensions will be identified and examined by constant comparison. Atlas.ti software allow us to code patient's perceptions, retrieve and perform more sophisticated analysis by the identification of key themes or categories and co-occurring codes in a range of logically overlapping possibilities. Semantical maps will be created and some theories suggested. As described by Pope et al.[(5)] the method of qualitative analysis has five stages: *familiarization* (reading questionnaires in order to list main ideas), *identifying* a thematic framework (mainly using key concepts), *indexing* (all the data in a systematic manner), *charting* (by abstraction and synthesis) and *mapping.* The ultimate purpose of this analytical exercise is to develop hypothesis and retest constructs. Conceptual maps will show relationships between codes and quotations expressed by participants with the view of providing explanations for the findings. The pilot study will be helpful activating all the processes for completing posterior full analysis.

So, following this approach, participants' interviews will be read and, key concepts related to obtrusiveness in these interviews will be identified. After that, coding, indexing and establishing logical semantical relationships between codes follows.

Indicators for measuring validity of the Radio system

Error! Reference source not found. reports, the ***ground truth*** observations/recordings that will be c onducted by the RA as well as the RADIO output. Ground truth will be compared to RADIO system output for the purposes of medical evaluation, i.e. the validity of the RADIO system for its medical purpose (the results of this analysis will be reported in *D6.15 Medical evaluation report III*).

Table 5. Ground truth and RADIO system output for each interRAI item.

interRAI item	***Ground Truth***	***RADIO output***
Bed transfer *(robot)*	***Duration of transfer (secs).*** The RA asks the participant to start performing the ADL and she also starts recording the time. When participant is in a standing position, this is the end of the recording. She writes down the duration of transfer.	***Duration of transfer (secs).*** Onset and total duration from lying down in bed to standing up position
Chair transfer *(robot)*	***Duration of transfer (secs).*** Then the RA asks the participant to perform the ADL and she starts the stopwatch. She stops it when the participant is in a fully upright position. She writes down the duration of transfer.	***Duration of transfer (secs).*** Onset and total duration from sitting on the chair or armchair to standing up position
4-meter walk *(robot)*	***Duration of walk (secs).*** The RA starts the stopwatch when the participant starts moving, and stops it when the participant has completed a 4 meters walk.	***Duration of walk (secs).*** The final output of this measurement will be the speed of the 4 meters (m/sec).
Pill intake *(robot)*	***The RA writes down the time when activity is initiated.***	***Confirmation of pill intake and time stamp***
TV watching. *(SH rule engine)*	***RA writes down the time when the participant started watching TV.***	***Time stamped events.*** This rule is based on: chair and armchair pressure sensor ON and TV ON
Going out of the room. *(SH rule engine)*	***RA writes down the time when the participant goes out of the room.***	***Time stamped events.*** This rule is based on: No activity in the room is detected and the magnetic sensor on the door disrupted.
Meal preparation *(SH rule engine)*	***RA writes down the time when the participant completed meal preparation.***	***Time stamped event.*** This rule is based on: Fridge door is closed and not any kitchen appliance is on (toaster, microwave, kettle and cooktop).

The updated data recording form to be filled by RAs for each participant is provided in Appendix I. The manual for the RA for operating the robot and the recording the ground truth is provided in Appendix III.

Statistical analysis

Statistical analysis regarding the *measures of usability* and *measuring the accuracy of activities of daily life (ADL) recognition* are described in Section 2.3.3 of D6.2.

2.2 Pilots at the private homes of FZ clients

2.2.1 Participants

Participants will be selected based on the inclusion and exclusion criteria as described in *D2.1 Early detection methods & relevant system requirements I*, coming from:

- Beneficiaries of FZ home care services
- Volunteers coming from the social care activities network of FZ

Ten (10) participants (private homes) will be involved in the final round of the summative phase of pilots. Each participant will work one week with the consortium; two days are planned for the deployment of RADIO system at private residences, while the actual pilot study will last for three days.

Participants will be selected based on the inclusion and exclusion criteria as described in *D2.1 Early detection methods & relevant system requirements I (*see *Section 2.4.2*). According to the last of the exclusion criteria for the summative phase of the trials, if a subject proves to be unable to operate the RADIO system during 2 training sessions he will be excluded.

2.2.2 Description of the pilot setting at private residences

The morphology of the subject's private homes may vary significantly. The effort of FZ will be to recruit elderly people that live in a house that permits the deployment of the RADIO robot in terms of space and setting of objects and furniture that might impede the robot. Other parameter required by the home users is to have internet connection installed into their homes. In cases that no internet connection is available, the technical team assigned for FZ use cases along with the team from FZ will elaborate alternatives (for example, wireless limited connection to the network).

The S&C ***Smart Home services*** to be installed in the private homes, as well as the related ADLs monitored and the sensors used are shown in the following Table 6. The sensors related to each service are detailed in Section 3.5.

Moreover, a set of BLE enabled devices will be installed to provide functionalities related to ***object detection and anti-theft services***.

The ***robot functionality*** in the private premises piloting scenarios will be to locate misplaced items. Participants will use the GUI to ask the robot to find their missing keys (which will be BLE-tagged). The robot will navigate to the room where the keys are.

Table 6. FZ Smart Home Services and related ADLs

Services	***Related ADLs***
Security (Flood, smoke, movement and intrusion detection)	**Going out of the house** (related to movement detection)
Control: To turn on/off equipment & scheduling (Lights, electric appliances)	**TV watching** (related to control of TV set)
Consumption: Information on electricity consumption and scheduling (Room electric consumption, Cooker)	N/A
Comfort: Knowledge about comfort values at home /Other smart home automations (Motion, Temperature, Light, Humidity, Vibration, UV)	N/A

2.2.3 Scenario Description

Illustrative scenario

Mrs Vasiliki is a 69-years old woman, she lives at home alone since her husband death 10 years ago, and she has two married daughters. She has a moderate mobility restriction due to ageing, but she is walking without help, although when outside she uses a cane.

A week before the deployment of the RADIO system in each private residence, the medical team of FZ composed by a formal caregiver and a social worker will visit and inform all the selected subjects upon the study's procedure. All the necessary information about the project, its objectives and the methodology of the trial will be analyzed to the participants and their relatives/caregivers. Moreover, all the possible risks and attitude towards the robot will be analysed. Once accepted to participate, all subjects will sign the informed consent form in order to start the training (Appendices I/IV/ D6.3).

Two days before the actual start of the pilots, TWG staff along with the formal caregiver of FZ will visit the participant candidates. TWG staff will start working on the deployment of the RADIO system (see Appendix V) while the formal caregiver will introduce the participants to the interface and train them into using the RADIO GUI in the following functionalities: control- turn on/off the lights, comfort – check ambient temperature and robot functionality. During the second day of deployment, FZ caregiver will be present if it is requested so by the participant.

At the first day of the pilot, FZ caregiver will visit Mrs Vasiliki at an arranged time in order to perform the standardized the Comprehensive Geriatric Assessment (CGA) using the interRAI HC (the MMSE is performed earlier in order to exclude from participants cognitively impaired people) and run the pilot schedule of the training day, as described in Table 7.

The rest of the days, we will work with 3 sub-scenarios at morning, lunch and dinner times where basic (bed transfer, chair transfer, 4 meters walk) and instrumental (pill intake) activities will take place (Table 7). The study finishes on day 3 with the fulfilment of usability questionnaires and the custom – made obtrusiveness questionnaire modified for FZ participants to a 5-level multiple choice questions (from least obtrusive to obtrusive).

Standard schedule

Table 7. Standard schedule for FZ pilot study scenario.

Day	Sub scenario	Schedule of events
D1 ***Training Day***	***Phase Baseline: Assessment 0***.	• Comprehensive Geriatric Assessment (CGA) by FZ formal caregiver. • Use of the Graphical User Interface[1] • Initial ADLs recording: Bed transfer, Chair transfer, Pill intake, 4 meters walk inside[2] .
D2 ***Study Day***	***Assessment 1***	• ADLs recording: Bed transfer, Chair transfer, Pill intake, 4 meters walk inside[2].
	Phase II* (*Lunch)	• TV watching sitting on BLE-tagged chair. • Use of the Graphical User Interface[1] • Chair transfer in front of TV • 4 meters walk inside • Pill intake - Lunch time medication (bed side table) • Bed transfer –Lunch nap • Chair transfer in another room (e.g. kitchen) using the BLE-tagged chair. • Additional ADLs recording: Bed transfer, Chair transfer, Pill intake, 4 meters walk inside
	Phase III (Dinner)	• Pill intake (Dinner time medication), Chair transfer, 4 meters walk inside[2].
D3 Study Day	***Phase I*** ***(Breakfast)***	• TV watching sitting on BLE-tagged chair. • Chair transfer in front of TV • 4 meters walk inside • Pill intake • Bed transfer • Chair transfer in another room (e.g. kitchen) using the BLE-tagged chair. • Additional ADLs recording: Bed transfer, Chair transfer, Pill intake, 4 meters walk inside. • Use of GUI for robot functionality. • End of the test. • Final assessments and usability, and obtrusiveness evaluation

The robot positions for recording the ADLs in case of private homes will be define during the technical visit. The updated data recording form to be filled by the FZ's formal caregiver for each participant is provided in Appendix II. The manual for the formal caregiver for operating the robot and recording the ground truth is provided in Appendix IV.

[1] control-turn on/off lamp, comfort –check temperature
[2] All ADLs are performed and recorded **twice**.

2.2.4 Evaluation Methods

Similar to Section 2.1.4, this section describes the evaluation methods for the private homes scenarios.

Evaluation of functional ADL

Functional status will be assessed with the interRAI HC instrument by the nurse of FZ in the beginning of the study. Section G regarding physical function, in particular, will be measured also at the end of the study. The Folstein's MMSE will be performed to all participants. In order to avoid drop outs because of the exclusion criteria based on MMSE, when inviting candidates, a sort of clinical assessment from recent medical records should be contemplated.

InterRAI HC was translated by FZ and was sent for verification of terminology to different doctors from the Patras region.

Usability measures

Usability will be evaluated in a similar way to the one described in 2.1.4.

Improving Quality of Life

In case of FZ, only the custom made questionnaire to assess dimensions of obtrusiveness will be used, as required in *D2.6 Balancing between medical requirements and obtrusiveness (Appendix VIII)*. In case of the FZ pilot studies, each participant will be asked to evaluate obtrusiveness based on a 5-level scale (from least obtrusive to most of obtrusive).

Indicators for measuring validity of the Radio system

Similar to what described in Section 2.1.4, ground truth observations will be conducted by the FZ nurse. Ground truth will be compared to RADIO system output for the purposes of medical evaluation, i.e. the validity of the RADIO system for its medical purpose (the results of this analysis will be reported in *D6.15 Medical evaluation report IV*). The data recording form to be filled by nurse in case of FZ scenarios is provided in Appendix II.

2.2.5 Evaluation of ease of installation of the RADIO system.

In this final round of pilot studies, we will evaluate the usability of the installation of the RADIO system in private residences.
A complete installation includes:

A) Setting up Raspberry Rack and the network.
B) Installing the Z-wave sensors and BLE enabled devices and confirming functionality.
C) Setting up the robot (mapping the house, setting the docking station, defining position for autonomous navigation where applicable, calibrating robot related ADLs).

The efficiency of the RADIO installation will be evaluated by recording the ***total installation time*** needed in each private residence. ***One working day*** will be considered as a success indicator.

Moreover, technical staff that have no prior experience with the RADIO system will be asked to install the RADIO system at TWG premises just by using the installation manual (Appendix V). The success indicator will be installing the system successfully in one working day.

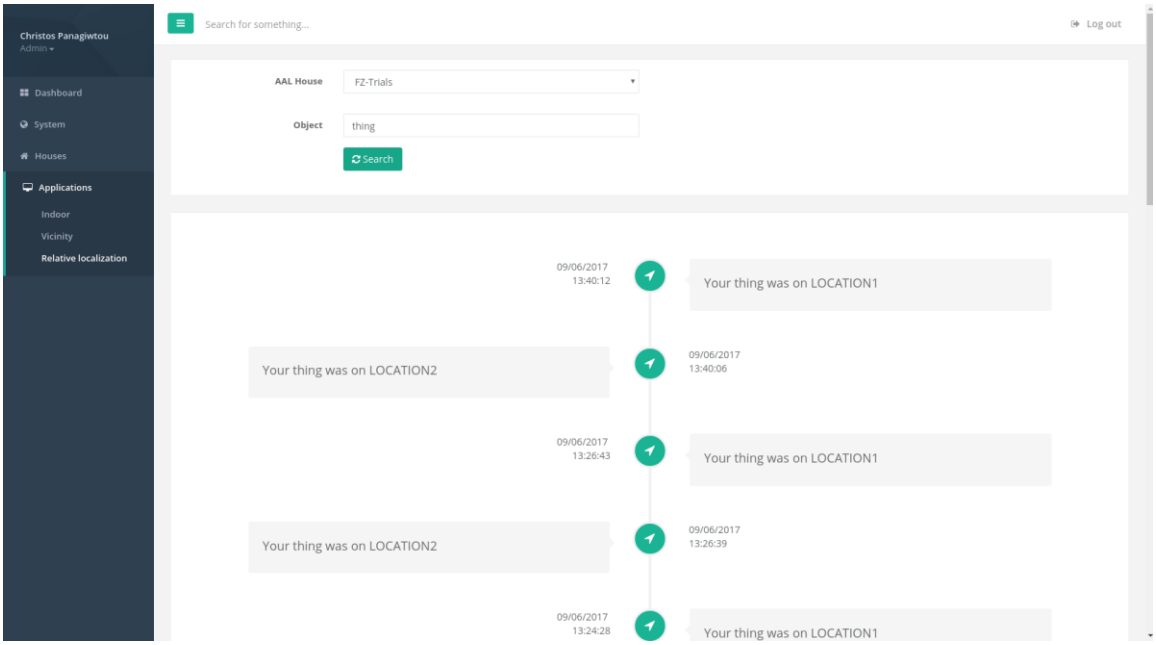

Figure 4. GUI used by caregiver to localize BLE-tagged objects.

2.2.6 Usability evaluation of RADIO system by the secondary users

At the end of the pilot studies at the private residences of FZ clients, the nurse in charge for executing them will deliver a brief report evaluating the RADIO system taking into account several aspects of the system, similarly to the questionnaire used in Section 3.2 of *D6.6 Controlled pilot trials report II*. Specifically, she will comment on:

- Aspects of the usability of the RADIO system
- The impact such as system can have in the caregiver's quality of life and work efficiency.
- The psycho-social impact to the primary user, as observed during the pilot studies,

In reference to evaluating the usability of the RADIO system, the caregiver interacts with the RADIO system to: a) execute the pilot and b) to use its functionalities. More specifically, she will use a separate GUI described in D5.9 that is targeted to secondary users of the RADIO system and offers a graphical tool that tracks the BLE-tagged objects (see Figure 4). The caregiver will use this GUI to search for the primary user's keys (movable object) and locate the robot (mobile object). She will do so in every visit to a participant's residence and keep a log of the expected and found location of the keys and robot, as well as issues observed in case that the robot was not found where expected.

2.3 Data Retention

Data retention procedures follow the same methodology and described in *D6.2 Piloting Planning II*/ Section 2.4.

3 TECHNICAL DETAILS

3.1 Graphical User Interface and Clinical Staff Update

During the Summative Phase of pilot studies, participants will use the *RADIO Graphical User Interface* (GUI) to interact with the robot (ask to be guided to the doctor's room) and to use Smart Home functionalities. This GUI has been developed and tested within Task 5.2 and it follows the requirements provided by previous studies (*D6.9 and D6.10: User evaluation report I/II).*

Clinical staff will receive an email with a report on recognized interRAI items upon completion of the study for each participant.

In addition, to the GUIs that are used as part of the RADIO home, an extra mobile app for facilitating ADL recording during the studies was developed (see Appendix XX). This app is not part of the RADIO System, but was developed in response to comments and issues regarding the piloting procedure during the first round of the Summative Phase (cf. D6.7, Section 4.2). The app makes it easier to orchestrate the robot's actions to follow the study design. The app also includes a timer, so that the caregiver can complete the session without needing any other device in their hands.

3.2 Communication between RADIO home components

The architecture of the different RADIO home components as it will be used in the Summative Phase pilot studies is described Deliverable 4.3.

3.3 Recognition methods and components

The following ADLs will be recorded:

- **Walking 4 meters** (time) – Laser scanner data processing for detecting movement, method described in D3.4,
- **Medication intake** – Image processing for detecting that a medicine cap is used, method described in D3.4,
- **Bed transfer** (time) – Image processing for detecting movement from a lying position to standing up, method described in D3.4,
- **Chair transfer** (time) – Image processing for detecting movement from a sitting position to standing up, described in D3.5,
- **Meal preparation** – Smart home sensors' event detection and decision based on rule engine described in D3.5.
- **TV watching** – Smart home sensors' event detection and decision based on rule engine described in D3.5,
- **Going in and out of home** – Smart home sensors' event detection and decision based on rule engine described in D3.5,

3.4 Robot Design and Robot Behaviour

The robotic platform used for the test will be the first design of the RADIO robot (Deliverable 4.7).

The robot will be composed by:

- The Turtlebot 2 mobile platform
- A Hokuyo UST10 LX laser
- An Orbbec RGBD camera
- On board NUC pc
- WiFi and Bluetooth Low Energy connectivity

In the FHAG pilot study, two locations have been selected as appropriate for observing ADLs. The robot will automatically position itself in these locations through the day to make measurements and also respond to user requests for robot guidance. The robot will dock itself to re-charge.

The experimenters are provided with remote control functionalities that force making measurements. This allows parallel system/ground truth measurements for experimentation and comparison.

3.5 Equipment for supporting Smart Home functionalities

Table 8 presents the Smart Home equipment installed by S&C at the FHAG premises for accommodating the smart home services listed.

Table 8. Smart Home Services and sensors /actuators.

Smart Home Services	**Sensors /Actuators**	**Deployed at**
Security-Flood sensing	Flood Sensor	FHAG
Security-Smoke sensing	Smoke Sensor	FHAG
Security-Presence sensor in the room	Presence sensor in the room	FHAG, FZ
Security- Magnetic Sensors on Door	Magnetic Sensors on: Door	FHAG, FZ
Control/*Comfort* of Lights	Smart switch –interrupter (kitchen light and room light)	FHAG, FZ
Control/*Comfort* air conditioning	Z-Wave-to-AC IR Extender	FHAG
Control /*Comfort* home environment (Motion, Temperature, Light, Humidity, Vibration, UV)	Multisensor 6 (x2)	FHAG, FZ
Control of shutters.	Connection with motors	FHAG
Control of electric appliances	Kettle/ Toaster/ Microwave /TV smart plugs	FHAG, FZ
Consumption of room energy	Z-Wave Smart Energy Meter	FHAG
Consumption of cooktop	Cooktop power consumption sensor	FHAG
Comfort	Pressure sensor under mattress	FHAG
Comfort	Pressure sensor under sofa	FHAG
Comfort	Pressure sensor under chair	FHAG, FZ
Comfort	Magnetic Sensors on: Fridge door/ Cupboards (3)	FHAG

In the case of FZ pilots, the following services will be available: *Control/Comfort* of Lights/TV, *Control* /*Comfort* of home environment and *Security* (movement/intrusion detection). Four types of sensors will be deployed in the private residences: one presence sensor, two smart plugs, one door sensor and one pressure sensor. In addition to S&C smart sensors, four BLE enabled devices will be installed in the residences of FZ's clients.

The scope of the BLE devices will be to monitor the location of mobile/movable objects throughout two of the most used rooms in the residence. Two devices will be stationary in the rooms chosen acting

as reference points for each room. The third BLE device will be attached to an object that the elder is most likely to search during the day. Finally, a raspberry pi device with the fourth device will be responsible for collecting the data from the wireless BLE nodes. The mobile BLE sensor advertises its presence to its surrounding space through beacons. The stationary nodes that captures the beacons propagate the presence event and the respected RSSI values recorded to the gateway (raspberry pi). Finally, the gateway is responsible to sort the RSSI values and extract the stationary node that is closer to the moving object.

The *smart plugs* will be attached to: a) the TV for measuring the consumption of TV set and b) a small/reading lamp for allowing the user to control through the GUI the light device. The *presence sensor* will be installed across the main entrance of the residence to monitor when the user exits/enters the house. In order to monitor more accurately the entering and exiting the house events, *a magnetic door sensor* will be deployed on the main entrance of each residence. Information from this sensor combined with the presence sensor is expected to offer more reliable indication on the aforementioned activity. Finally, the *pressure sensor* will be used in combination with the smart plug on the TV to detect the TV-watching ADL. A BLE-tagged chair will be used in the TV watching scenarios to rule out false positives when the TV is on but the user sits on the chair in another room.

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APPENDICES

APPENDIX I

Data recording form to be filled for each participant by RAs during the 2nd round of Summative Phase pilot studies at FHAG premises.

DATA RECORDING QUESTIONNAIRE version 5

CASE NUMBER 1 [ ][ ]

Code 0 = No
Code 1 = Yes
Time in seconds
Gray boxes do not code

Variables for Sub scenario Assessment 0: D1 Training Day

T0a Assessment 0 SubscenarioRound 1 [ ]

V1a Bed Transfer occurs, detected by Research Assistant (RA), [ ]

V2a Bed Transfer occurs, detected by RADIO [ ]

V3a Time elapsed for bed transfer by RA (seconds) [ ][ ][ ][ ]

V4a Time elapsed for bed transfer by RADIO (seconds) [ ][ ][ ][ ]

V5a Armchair transfer occurs, detected by RA [ ]

V6a Armhair transfer occurs, detected by RADIO [ ]

V7a Time elapsed for armchair transfer by RA [ ][ ][ ][ ]

V8a Time elapsed for armchair transfer by RADIO [ ][ ][ ][ ]

V9a Pill intake occurs by RA [ ]

V10a Pill intake occurs by RADIO [ ]

V11a Time elapsed for 4 meters walk inside SCRSA by RA [ ][ ][ ][ ]

V12a Time elapsed for 4 meters walk inside SCRSA by RADIO [ ][ ][ ][ ]

Variables for Sub scenario Assessment 0: D1 Training Day

T0b Assessment 0 SubscenarioRound 2 [ ]

V1b Bed Transfer occurs, detected by Research Assistant (RA), [ ]

V2b Bed Transfer occurs, detected by RADIO [ ]

V3bTime elapsed for bed transfer by RA (seconds) [ ][ ][ ][ ]

V4b Time elapsed for bed transfer by RADIO (seconds) [ ][ ][ ][ ]

V5b Armchair transfer occurs, detected by RA [ ]

V6b Armchair transfer occurs, detected by RADIO [ ]

V7b Time elapsed for armchair transfer by RA [ ][ ][ ][ ]

V8b Time elapsed for armchair transfer by RADIO [ ][ ][ ][ ]

V9b Pill intake occurs by RA [ ]

V10b Pill intake occurs by RADIO [ ]

V11b Time elapsed for 4 meters walk inside SCRSA by RA [ ][ ][ ][ ]

V12b Time elapsed for 4 meters walk inside SCRSA by RADIO [ ][ ][ ][ ]

DATA RECORDING QUESTIONNAIRE

CASE NUMBER [1][ ][ ]

Code 0 = No
Code 1 = Yes
Time in seconds
Gray boxes do not code

Variables for Sub scenario Assessment 1: D2 Study Day

T220a Assessment 1 SubscenarioRound 1 [ ]

V221a Bed Transfer occurs, detected by Research Assistant (RA), [ ]

V222a Bed Transfer occurs, detected by RADIO [ ]

V223a Time elapsed for bed transfer by RA (seconds) [ ][ ][ ][ ]

V224a Time elapsed for bed transfer by RADIO (seconds) [ ][ ][ ][ ]

V225a Armhair transfer occurs, detected by RA [ ]

V226a Armhair transfer occurs, detected by RADIO [ ]

V227a Time elapsed for armchair transfer by RA [ ][ ][ ][ ]

V228a Time elapsed for armchair transfer by RADIO [ ][ ][ ][ ]

V229a Pill intake occurs by RA [ ]

V210a Pill intake occurs by RADIO [ ]

V211a Time elapsed for 4 meters walk inside SCRSA by RA [ ][ ][ ][ ]

V212a Time elapsed for 4 meters walk inside SCRSA by RADIO [ ][ ][ ][ ]

Variables for Sub scenario Assessment 1: D2 Study Day

T220b Assessment 1 SubscenarioRound 2 [ ]

V221b Bed Transfer occurs, detected by Research Assistant (RA), [ ]

V222b Bed Transfer occurs, detected by RADIO [ ]

V223bTime elapsed for bed transfer by RA (seconds) [ ][ ][ ][ ]

V224b Time elapsed for bed transfer by RADIO (seconds) [ ][ ][ ][ ]

V225b Armhair transfer occurs, detected by RA [ ]

V226b Armhair transfer occurs, detected by RADIO [ ]

V227b Time elapsed for armchair transfer by RA [ ][ ][ ][ ]

V228b Time elapsed for armchair transfer by RADIO [ ][ ][ ][ ]

V229b Pill intake occurs by RA [ ]

V210b Pill intake occurs by RADIO [ ]

V211b Time elapsed for 4 meters walk inside SCRSA by RA [ ][ ][ ][ ]

V212b Time elapsed for 4 meters walk inside SCRSA by RADIO [ ][ ][ ][ ]

DATA RECORDING QUESTIONNAIRE

CASE NUMBER 1 _ _

Code 0 = No
Code 1 = Yes
Time in seconds

Variables for Sub scenario Lunch: D2 Study Day

T2a Lunch Subscenario Round 1 _

V21a Pill intake occurs by RA _

V22a Pill intake occurs by RADIO _

V23a Time elapsed for 4 meters walk inside SCRSA by RA _ _ _ _

V24a Time elapsed for 4 meters walk inside SCRSA by RADIO _ _ _ _

V25a Armhair transfer occurs, detected by RA _

V26a Armchair transfer occurs, detected by RADIO _

V27a Time elapsed for armchair transfer by RA _ _ _ _

V28a Time elapsed for armchair transfer by RADIO _ _ _ _

V29a Time elapsed for 4 meters walk inside SCRSA by RA _ _ _ _

V30a Time elapsed for 4 meters walk inside SCRSA by RADIO _ _ _ _

V31a Armchair transfer occurs, detected by RA _

V32a Armchair transfer occurs, detected by RADIO _

V33a Time elapsed for armchair transfer by RA _ _ _ _

V34a Time elapsed for armchair transfer by RADIO _ _ _ _

V35a Bed Transfer occurs, detected by RA _

V36a Bed Transfer occurs, detected by RADIO _

V37a Time elapsed for bed transfer by RA (seconds) _ _ _ _

V38a Time elapsed for bed transfer by RADIO (seconds) _ _ _ _

V39a TV watching, detected by (RA) _ _ _ _

V40a TV watching, detected by RADIO _ _ _ _

V41a GUI use before living the apartment _

V42a GUI detecting no presence (time going-out) _ _ _ _

Variables for Sub scenario Lunch: D2 Study Day

T2b Lunch Subscenario Round 2 _

V21b Pill intake occurs by RA _

V22b Pill intake occurs by RADIO _ _ _ _

V23b Time elapsed for 4 meters walk inside SCRSA by RA _ _ _ _

V24b Time elapsed for 4 meters walk inside SCRSA by RADIO _ _ _ _

V25b Armchair transfer occurs, detected by RA _

V26b Armchair transfer occurs, detected by RADIO _

V27b Time elapsed for armchair transfer by RA _ _ _ _

V28b Time elapsed for armchair transfer by RADIO _ _ _ _

V29b Time elapsed for 4 meters walk inside SCRSA by RA _ _ _ _

V30b Time elapsed for 4 meters walk inside SCRSA by RADIO _ _ _ _

V31b Armchair transfer occurs, detected by RA _

V32b Armchair transfer occurs, detected by RADIO _

V33b Time elapsed for armchair transfer by RA _ _ _ _

V34b Time elapsed for armchair transfer by RADIO _ _ _ _

V35b Bed Transfer occurs, detected by RA _

V36b Bed Transfer occurs, detected by RADIO _

V37b Time elapsed for bed transfer by RA (seconds) _ _ _ _

V38b Time elapsed for bed transfer by RADIO (seconds) _ _ _ _

V39b TV watching, detected by (RA) _ _ _ _

V40b TV watching, detected by RADIO _ _ _ _

V41b GUI use before living the apartment _

V42b GUI detecting no presence (time going-out) _ _ _ _

DATA RECORDING QUESTIONNAIRE

CASE NUMBER 1

Variables for Sub scenario dinner: D2 StudyDay

T3a Dinner Subscenario Round 1

V43a Pill intake occurs by RA

V44a Pill intake occurs by RADIO

V45a Chair transfer occurs, detected by RA

V46a Chair transfer occurs, detected by RADIO

V47a Time elapsed for chair transfer by RA

V48a Time elapsed for chair transfer by RADIO

V49a Time elapsed for 4 meters walk inside SCRSA by RA

V50a Time elapsed for 4 meters walk inside SCRSA by RADIO

V51a Meal preparation occurs, detected by RA

V52a Meal preparation occurs, detected by RADIO

V53a GUI interaction TV watching set turn off

Variables for Sub scenario dinner: D2 StudyDay

T3a Dinner Subscenario Round 2

V43b Pill intake occurs by RA

V44b Pill intake occurs by RADIO

V45b Chair transfer occurs, detected by RA

V46b Chair transfer occurs, detected by RADIO

V47b Time elapsed for chair transfer by RA

V48b Time elapsed for chair transfer by RADIO

V49b Time elapsed for 4 meters walk inside SCRSA by RA

V50b Time elapsed for 4 meters walk inside SCRSA by RADIO

V51b Meal preparation occurs, detected by RA

V52b Meal preparation occurs, detected by RADIO

V53b GUI interaction TV watching set turn off)

Variables for Sub scenario breakfast: D3 Study Day

T1a Breakfast SubscenarioRound 1

V54a Bed Transfer occurs, detected by Research Assistant (RA),

V55a Bed Transfer occurs, detected by RADIO

V56a Time elapsed for bed transfer by RA (seconds)

V57a Time elapsed for bed transfer by RADIO (seconds)

V58a Armchair transfer occurs, detected by RA

V59a Armchair transfer occurs, detected by RADIO

V60a Time elapsed for armchair transfer by RA

V61a Time elapsed for armchair transfer by RADIO

V62a Pill intake occurs by RA

V63a Pill intake occurs by RADIO

V64a Time elapsed for 4 meters walk inside SCRSA by RA

V65a Time elapsed for 4 meters walk inside SCRSA by RADIO

V66a Meal preparation occurs, detected by RA

V67a Meal preparation occurs, detected by RADIO

Variables for Sub scenario breakfast: D3 Study Day

T1b Breakfast SubscenarioRound 2

V54b Bed Transfer occurs, detected by Research Assistant (RA),

V55b Bed Transfer occurs, detected by RADIO

V56bTime elapsed for bed transfer by RA (seconds)

V57b Time elapsed for bed transfer by RADIO (seconds)

V58b ARmhair transfer occurs, detected by RA

V59b Armhair transfer occurs, detected by RADIO

V60b Time elapsed for armchair transfer by RA

V61b Time elapsed for armchair transfer by RADIO

V62b Pill intake occurs by RA

V63b Pill intake occurs by RADIO

V64b Time elapsed for 4 meters walk inside SCRSA by RA

V65b Time elapsed for 4 meters walk inside SCRSA by RADIO

V66b Meal preparation occurs, detected by RA

V67b Meal preparation occurs, detected by RADIO

DATA RECORDING QUESTIONNAIRE

CASE NUMBER 1 ☐☐

Code 0 = No
Code 1 = Yes
Time in seconds

Variables for Sub scenario Oupatient visit: D3 StudyDay

T4a Outpatient's Visit Subscenario Round 1 ☐

V68a Activaton via GUI occurs by RA ☐

V69a Activation via GUI occurs by RADIO ☐

V70a Time elapsed for 4 meters walk outside SCRSA by RA ☐☐☐☐

V71a Time elapsed for 4 meters walk outside SCRSA by RADIO ☐☐☐☐

V72a Patient in OP, detected by RA ☐

V73a Patient out, detected by RA ☐

V74a Activaton via GUI occurs by RA ☐

V75a Activation via GUI occurs by RADIO ☐

V76a Time elapsed for 4 meters walk to SCRSA by RA ☐☐☐☐

V77a Time elapsed for 4 meters walk to SCRSA by RADIO ☐☐☐☐

V78a End of the study (desactivation GUI) ☐

Variables for Sub scenario Oupatient visit: D3 StudyDay

T4a Outpatient's Visit Subscenario Round 2 ☐

V68b Activaton via GUI occurs by RA ☐

V69b Activation via GUI occurs by RADIO ☐

V70b Time elapsed for 4 meters walk outside SCRSA by RA ☐☐☐☐

V71b Time elapsed for 4 meters walk outside SCRSA by RADIO ☐☐☐☐

V72b Patient in OP, detected by RA ☐

V73b Patient out, detected by RA ☐

V74b Activaton via GUI occurs by RA ☐

V75b Activation via GUI occurs by RADIO ☐

V76b Time elapsed for 4 meters walk to SCRSA by RA ☐☐☐☐

V77b Time elapsed for 4 meters walk to SCRSA by RADIO ☐☐☐☐

V78b End of the study (desactivation GUI) ☐

Following evaluation of functional status with this questionnaire the following tests will be carried out on each patient by the Research Assistant.

.- Self perceived Quality of Life (for LTCF clients only, second round)
.- in-depth semistructured questionnaire on obtrusiveness
.- usability measures (USU, ASQ and PIADS)

APPENDIX II

Data recording form to be filled for each participant by the formal caregiver during the 2nd round of Summative Phase pilot studies at FZ private residences.

DATA RECORDING QUESTIONNAIRE for FZ private residences pilot studies CASE NUMBER

1 | | |

Code 0 = No
Code 1 = Yes
Time in seconds

Gray boxes do not code

Variables for Sub scenario Assessment 0: D1 Training Day

T0a Assessment 0 Subscenario Round 1 | |

V1a Bed Transfer occurs, detected by formal caregiver (CG) | |

V2a Bed Transfer occurs, detected by RADIO | |

V3a Time elapsed for bed transfer by CG (seconds) | | | | |

V4a Time elapsed for bed transfer by RADIO (seconds) | | | | |

V5a Armchair transfer occurs, detected by CG | |

V6a Armchair transfer occurs, detected by | |

RADIO V7a Time elapsed for armchair transfer | | | | |

by CG V8a Time elapsed for armchair transfer by | | | | |

RADIO V9a Pill intake occurs by CG | |

V10a Pill intake occurs by RADIO | |

V11a Time elapsed for 4 meters walk by CG | | | | |

V12a Time elapsed for 4 meters walk by RADIO | | | | |

Variables for Sub scenario Assessment 0: D1 Training Day

T0b Assessment 0 Subscenario Round 2 | |

V1b Bed Transfer occurs, detected by formal caregiver (CG) | |

V2b Bed Transfer occurs, detected by RADIO | |

V3bTime elapsed for bed transfer by CG (seconds) | | | | |

V4b Time elapsed for bed transfer by RADIO (seconds) | | | | |

V5b Armchair transfer occurs, detected by CG | |

V6b Armchair transfer occurs, detected by RADIO | |

V7b Time elapsed for armchair transfer by CG | | | | |

V8b Time elapsed for armchair transfer by RADIO | | | | |

V9b Pill intake occurs by CG | |

V10b Pill intake occurs by RADIO | |

V11b Time elapsed for 4 meters walk by CG | | | | |

V12b Time elapsed for 4 meters walk by RADIO | | | | |

DATA RECORDING QUESTIONNAIRE

CASE NUMBER

1 | | |

Code 0 = No

Code 1 = Yes

Time in seconds

Gray boxes do not code

Variables for Sub scenario Assessment 1: D2 Study Day

T220a Assessment 1 Subscenario Round 1 | |

V221a Bed Transfer occurs, detected by GC | |

V222a Bed Transfer occurs, detected by RADIO | |

V223a Time elapsed for bed transfer by CG (seconds) | | | | |

V224a Time elapsed for bed transfer by RADIO (seconds) | | | | |

V225a Armchair transfer occurs, detected by CG | |

V226a Armchair transfer occurs, detected by RADIO | |

V227a Time elapsed for armchair transfer by CG | | | | |

V228a Time elapsed for armchair transfer by RADIO | | | | |

V229a Pill intake occurs by CG | |

V210a Pill intake occurs by RADIO | |

V211a Time elapsed for 4 meters walk by CG | | | | |

V212a Time elapsed for 4 meters walk by RADIO | | | | |

Variables for Sub scenario Assessment 1: D2 Study Day

T220b Assessment 1 Subscenario Round 2 | |

V221b Bed Transfer occurs, detected by CG | |

V222b Bed Transfer occurs, detected by RADIO | |

V223bTime elapsed for bed transfer by CG (seconds) | | | | |

V224b Time elapsed for bed transfer by RADIO (seconds) | | | | |

V225b Armchair transfer occurs, detected by CG | |

V226b Armchair transfer occurs, detected by RADIO | |

V227b Time elapsed for armchair transfer by CG | | | | |

V228b Time elapsed for armchair transfer by RADIO | | | | |

V229b Pill intake occurs by CG | |

V210b Pill intake occurs by RADIO | |

V211b Time elapsed for 4 meters walk by CG | | | | |

V212b Time elapsed for 4 meters walk by RADIO | | | | |

DATA RECORDING QUESTIONNAIRE

CASE NUMBER 1 [ ] [ ]

Code 0 = No
Code 1 = Yes
Time in seconds

Variables for Sub scenario Lunch: D2 Study Day

T2a Lunch Subscenario Round 1 [ ]

V21a Pill intake occurs by CG [ ]

V22a Pill intake occurs by RADIO [ ]

V23a Time elapsed for 4 meters walk by CG [ ][ ][ ][ ]

V24a Time elapsed for 4 meters walk by RADIO [ ][ ][ ][ ]

V25a Armhair transfer occurs, detected by CG [ ]

V26a Armchair transfer occurs, detected by RADIO [ ]

V27a Time elapsed for armchair transfer by CG [ ][ ][ ][ ]

V28a Time elapsed for armchair transfer by RADIO [ ][ ][ ][ ]

V29a Time elapsed for 4 meters walk by CG [ ][ ][ ][ ]

V30a Time elapsed for 4 meters walk by RADIO [ ][ ][ ][ ]

V31a Armchair transfer occurs, detected by CG [ ]

V32a Armchair transfer occurs, detected by RADIO [ ]

V33a Time elapsed for armchair transfer by CG [ ][ ][ ][ ]

V34a Time elapsed for armchair transfer by RADIO [ ][ ][ ][ ]

V35a Bed Transfer occurs, detected by CG [ ]

V36a Bed Transfer occurs, detected by RADIO [ ]

V37a Time elapsed for bed transfer by CG (seconds) [ ][ ][ ][ ]

V38a Time elapsed for bed transfer by RADIO (seconds) [ ][ ][ ][ ]

V39a TV watching, detected by (CG) [ ][ ][ ][ ]

V40a TV watching, detected by RADIO [ ][ ][ ][ ]

V41a GUI use for controlling lights [ ]

Variables for Sub scenario Lunch: D2 Study Day

T2b Lunch Subscenario Round 2 [ ]

V21b Pill intake occurs by CG V22b [ ]

Pill intake occurs by RADIO [ ]

V23b Time elapsed for 4 meters walk by CG [ ][ ][ ][ ]

V24b Time elapsed for 4 meters walk by RADIO [ ][ ][ ][ ]

V25b Armchair transfer occurs, detected by CG [ ]

V26b Armchair transfer occurs, detected by RADIO [ ]

V27b Time elapsed for armchair transfer by CG [ ][ ][ ][ ]

V28b Time elapsed for armchair transfer by RADIO [ ][ ][ ][ ]

V29b Time elapsed for 4 meters walk by CG [ ][ ][ ][ ]

V30b Time elapsed for 4 meters walk by RADIO [ ][ ][ ][ ]

V31b Armchair transfer occurs, detected by CG [ ]

V32b Armchair transfer occurs, detected by RADIO [ ]

V33b Time elapsed for armchair transfer by CG [ ][ ][ ][ ]

V34b Time elapsed for armchair transfer by RADIO [ ][ ][ ][ ]

V35b Bed Transfer occurs, detected by CG [ ]

V36b Bed Transfer occurs, detected by RADIO [ ]

V37b Time elapsed for bed transfer by CG (seconds) [ ][ ][ ][ ]

V38b Time elapsed for bed transfer by RADIO (seconds) [ ][ ][ ][ ]

V39b TV watching, detected by (CG) [ ][ ][ ][ ]

V40b TV watching, detected by RADIO [ ][ ][ ][ ]

V41b GUI use for controlling lights [ ]

DATA RECORDING QUESTIONNAIRE

CASE NUMBER 1

Variables for Sub scenario dinner: D2 StudyDay

T3a Dinner Subscenario Round 1

V43a Pill intake occurs by CG

V44a Pill intake occurs by RADIO

V45a Chair transfer occurs, detected by CG

V46a Chair transfer occurs, detected by RADIO

V47a Time elapsed for chair transfer by CG

V48a Time elapsed for chair transfer by RADIO

V49a Time elapsed for 4 meters walk by CG

V50a Time elapsed for 4 meters walk by RADIO

V531a TV watching, detected by CG

V532a TV watching, detected by RADIO

V53a GUI interaction for controlling lights

Variables for Sub scenario dinner: D2 StudyDay

T3a Dinner Subscenario Round 2

43b Pill intake occurs by CG

V44b Pill intake occurs by RADIO

V45b Chair transfer occurs, detected by CG

V46b Chair transfer occurs, detected by RADIO

V47b Time elapsed for chair transfer by CG

V48b Time elapsed for chair transfer by RADIO

V49b Time elapsed for 4 meters walk by CG

V50b Time elapsed for 4 meters walk by RADIO

V531b TV watching, detected by CG

V532b TV watching, detected by RADIO

V53b GUI interaction for controlling lights

Variables for Sub scenario breakfast: D3 Study Day

T1a Breakfast SubscenarioRound 1

V54a Bed Transfer occurs, detected by CG,

V55a Bed Transfer occurs, detected by RADIO

V56a Time elapsed for bed transfer by CG (seconds)

V57a Time elapsed for bed transfer by RADIO (seconds)

V58a Armchair transfer occurs, detected by CG

V59a Armchair transfer occurs, detected by RADIO

V60a Time elapsed for armchair transfer by CG

V61a Time elapsed for armchair transfer by RADIO

V62a Pill intake occurs by CG

V63a Pill intake occurs by RADIO

V64a Time elapsed for 4 meters walk by CG

V65a Time elapsed for 4 meters walk by RADIO

Variables for Sub scenario breakfast: D3 Study Day

T1b Breakfast SubscenarioRound 2

V54b Bed Transfer occurs, detected by Research Assistant (CG),

V55b Bed Transfer occurs, detected by RADIO

V56bTime elapsed for bed transfer by CG (seconds)

V57b Time elapsed for bed transfer by RADIO (seconds)

V58b Armchair transfer occurs, detected by CG

V59b Armchair transfer occurs, detected by RADIO

V60b Time elapsed for armchair transfer by CG

V61b Time elapsed for armchair transfer by RADIO

V62b Pill intake occurs by CG

V63b Pill intake occurs by RADIO

V64b Time elapsed for 4 meters walk by CG

V65b Time elapsed for 4 meters walk by RADIO

DATA RECORDING QUESTIONNAIRE

CASE NUMBER

1		

Code 0 = No

Code 1 = Yes

Time in seconds

Regarding 'Going out' ADL, in case of FZ pilot studies, the caregiver will report all ins and outs of the private residence during the pilot study.

Following evaluation of functional status with this questionnaire the following tests will be carried out on each patient by the Research Assistant.

- Self perceived Quality of Life (for LTCF clients only, second round)

- in-depth semistructured questionnaire on obtrusiveness

- usability measures (SUS, ASQ and PIADS)

APPENDIX III

Research assistant's manual for the 2nd round of Summative Phase pilot studies at FHAG premises.

ROBOTS IN ASSISTED
LIVING ENVIRONMENTS

UNOBTRUSIVE, EFFICIENT, RELIABLE AND MODULAR SOLUTIONS FOR INDEPENDENT AGEING

Research Innovation Action

Project Number: 643892 Start Date of Project: 01/04/2015 Duration: 36 months

Research assistant's manual for the 2nd round of summative phase pilot study at FHAG premises

Project funded by the European Union's Horizon 2020 Research and Innovation Actions

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1 ROBOT POSITIONS DURING THE PILOTING SCHEDULE

Figure 1 shows the positions the robot can take during the pilot study. Table 1 relates these positions to the piloting schedule.

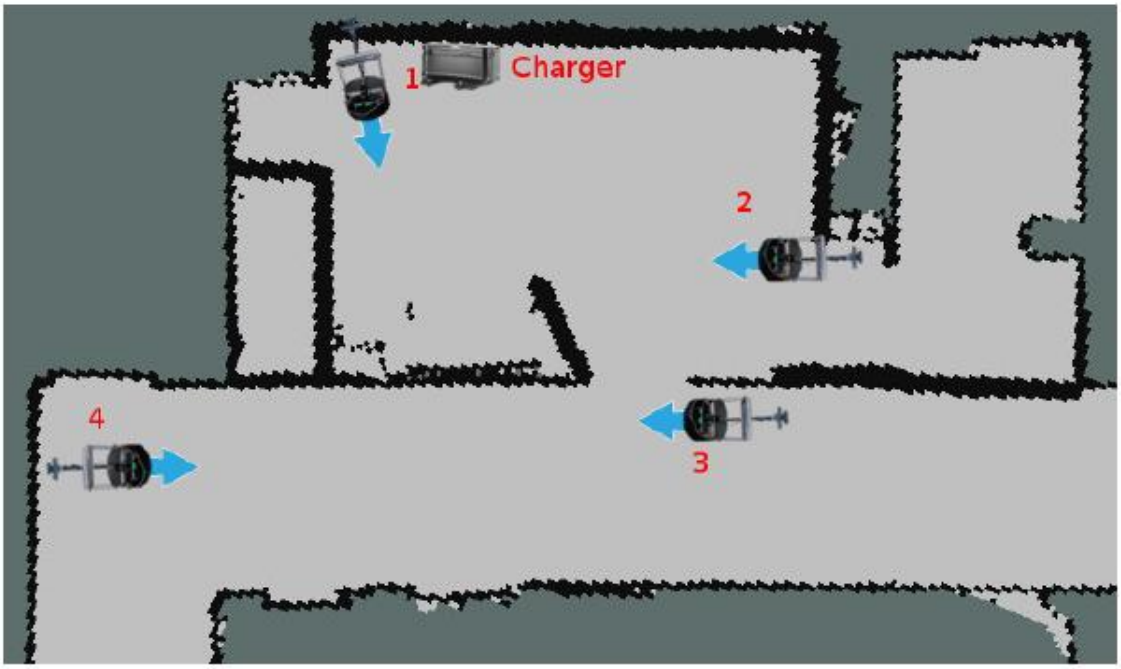


Figure 1. Robot positions during the piloting scenario

- Position 1 should be rotated towards the armchair (couch).
- Positions 3 and 4 are the ones used by the android application. Position 4 is the Doctor's Office, and position 3 is the participant's room (My Room).
- **Bed transfer** should be recorded **only** from **robot position 1**.
- Depending on the robot position (1 or 2) the **pill box position** should be either on the bedside table or on the dining table accordingly (see Figures 2 and 3).
- The door of the participant's room should be closed when the robot is in position 2, so that the armchair is visible.
- In any other case, the door of the participant's room should stay opened, especially when the participant needs the robot to lead them to one of the rooms used in the android application.

Table 1. Piloting schedule for FHAG and related robot positions

Day	***Sub scenario***	***Robot monitoring***	***Robot Position***
D1 Training Day	***Phase Baseline: Assessment 0.***	• Bed transfer • Armchair transfer • Pill intake • 4 meters walk inside	• **1** • **1** • **1** • **1**
D2 Study Day	***Phase Baseline: Assessment I***	• Bed transfer • Armchair transfer • Pill intake • 4 meters walk inside	• **1** • **1** • **1** • **1**
	Phase II (Lunch)	• Pill intake • 4 meters walk inside • Armchair transfer • 4 meters walk inside • Armchair transfer • Bed transfer	• **1** • **1** • **1** • **1** • **1** • **1**
	Phase III (Dinner)	• Pill intake • Chair transfer • 4 meters walk inside	• **2** • **2** • **2**
D3 Study Day	***Phase I (Breakfast)***	• Bed transfer • Armchair transfer • Pill intake • 4 meters walk inside	• **1** • **1** • **1** • **1**
	Phase I (Outpatient's Visit)	• 4 meters walking test Going to OP • 4 meters walking test Coming from OP	• **3** • **4**

Figure 2. Pill box position for robot position 1.

Figure 3. Pill box position for robot position 2.

2 COLLECTING GROUND TRUTH VALUES FOR THE ADLS

This section describes the details for recording ground truth values for the ADLs that are monitored by the robot. The instructions in Table 2 take into account how each method works.

Table 2. Ground truth collection for each ADL robot method.

ADL method	Instructions for collecting ground truth
Bed Transfer	This method plays a sound when the system starts recording (**after about 5 seconds**). At that time, the caregiver should start their stopwatch, and stop it when the participant is in a fully upright position. Bed transfer is **only** recorded from **robot position 1.**
Pill Intake ADL	This method starts checking for pill movement **after 5 seconds**. Any movement inside a small area around the pill box will be registered as a successful pill intake, thus the caregiver should always place the pill box in the correct position, and then enable the method using the gamepad. For pill positions, consult Figures 2 and 3 in the previous section.
Sit to Stand ADL	For this method, it is recommended to start with the patient standing up. When the caregiver starts the method the participant approaches the chair/armchair to sit down. The caregiver should start their stopwatch as soon as the participant starts standing up from a sitting position, and stop it when the participant is in a fully upright position. It should be noted, that this ADL can be recorded either using the armchair or a table chair. Use **robot position 1** for recording **sit-to-stand from the armchair**, and **robot position 2** for recording **sit-to stand from the table chair**.
4 meters walking ADL	This method should always be started **without any feet visible** (participant's or caregiver's). This helps the robot determine easily the moving target. The caregiver should start their stopwatch when the participant starts moving, and stop it when the participant has completed a 4 meters walk. Please note that if the caregiver is inside the robot's field of view and stays completely still, it won't negatively affect the method's performance. The caregiver should use floor tiles to measure and mark a distance of 4 meters.
For all ADLs: after hearing the initialization sound the participant waits 5-10 seconds to start the ADL activity, the time when the research assistant will start the stopwatch on the application. Once the participant finishes the ADL activity the research assistant stops the stopwatch and waits 5-10 seconds to stop the robot recording. At this time a finalization sound is heard.	

3 ROBOT CONTROL VIA THE GAMEPAD

This section provides the guidelines on how to control the robot via the gamepad (see Table 2 below).

Table 3. Gamepad controls

SIDE GAMEPAD VIEW

TOP GAMEPAD VIEW

D-pad Up	Initialize Robot Position (in front of the sticker)
D-pad Down	Clear Obstacles on Robot's Map
LB	Stop robot's movement (for as long as it's pressed)
LB+LeftStick	Control robot's linear velocity
LB+RightStick	Control robot's angular velocity
RT+RightStick [Pressed]	Enable Auto-Docking [1] (charging)
Start	Send report for the latest participant
Back	Cancel navigation goal
X	Start 4 meter walking ADL
RT+X	Stop 4 meter walking ADL
A	Start Chair Transfer ADL
RT+A	Stop Chair Transfer ADL
B	Start Bed Transfer ADL
RT+B	Stop Bed Transfer ADL
Y	Start Pill Intake ADL
RT+Y	Stop Pill Intake ADL
RT +RB **OR** RT+D-pad Left	Robot position 2
RT+D-pad Right **OR** RT+ LeftStick [Pressed]	Robot position 1

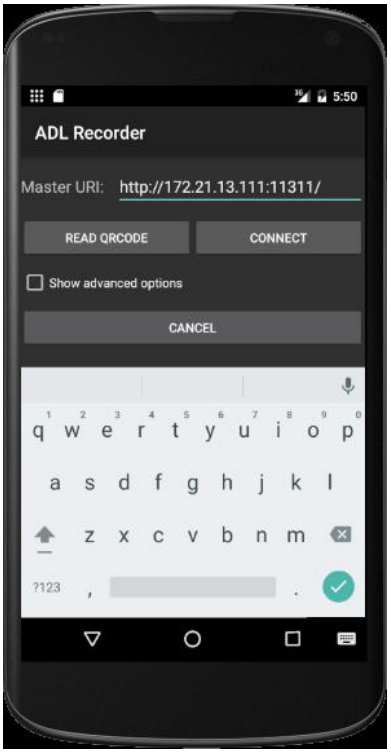
[1] In this function the robot should be placed in front of the docking station, keeping a distance of at least half a meter, but no more than a meter.

Important notes!

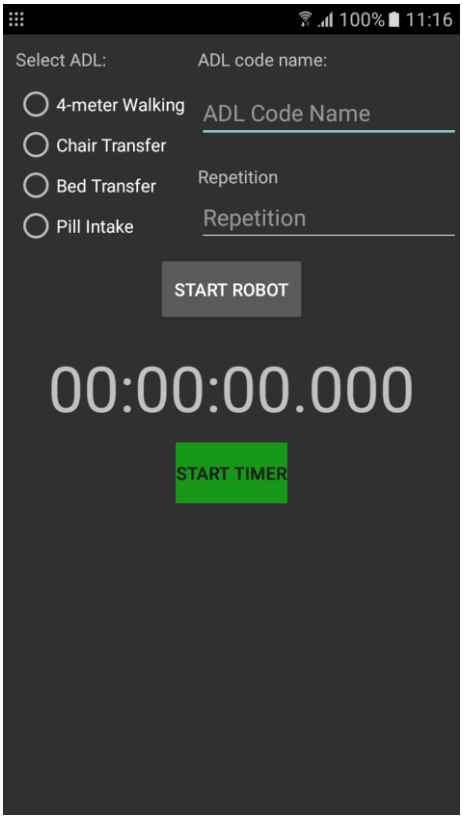
- You will always hear a sound that confirms that your command was accepted.
- If you don't hear a sound, you can try sending your desired command again.
- Back button stops the robot from moving until another command is sent to it.
- LB button stops the robot for as long as the button is pressed.
- All combinations of buttons that include RT, should be used in the following order:
    - Press and keep RT
    - Press the other button
    - Release the other button
    - Release RT
- Always make sure that the gamepad's input is switched to 'X' (and not 'D').
- Bed Transfer and Pill Intake ADLs need about 5 seconds to initialize.
- In case of a failure in the recording, the caregiver has to take a note of the failed recording (like they would do with a successful one) and repeat the ADL by following the normal procedure. (The failed recording should be included in the RA report)

4 RECORDING ADLS VIA THE MOBILE APPLICATION

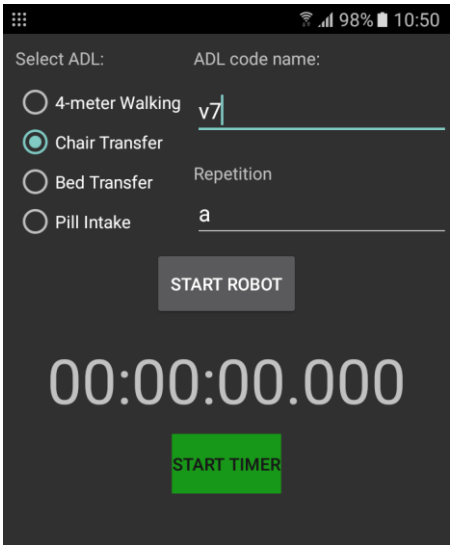
The use of the Android ADL Recorder aims to reduce the difficulties the caregivers face while recording ADLs, and at the same time reduce human errors.



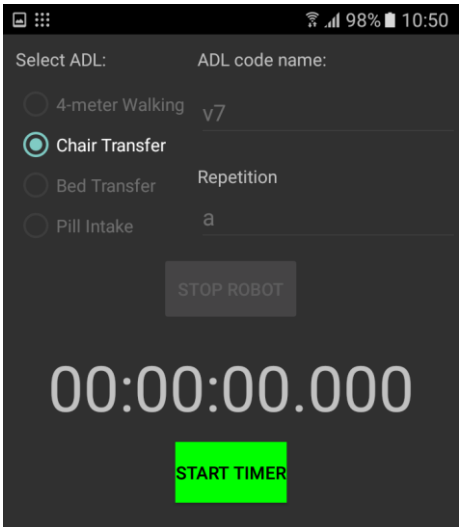
The application starts in the Connection Screen where the caregiver has to ensure that the Master URI is set to http://172.21.13.111:11311/. This address has to be set only the first time, as it is then saved automatically. Before pressing connect, the caregiver should **make sure that the device is connected to the RADIO-dedicated network**.



When connect is pressed and given that the connection was successful, the **Main Screen** is shown. This is where the caregiver can send commands to the robot and also use the built-in timer to record the ground truth for each ADL. The process is completely streamlined, leaving no room for alternative choices.

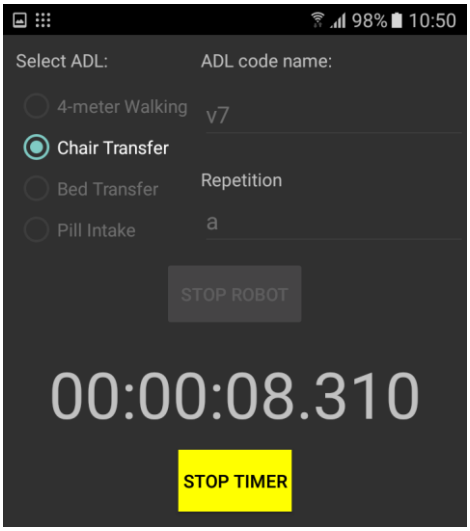


- The caregiver has to **select an ADL** from the top left section of the screen, then **type an ADL code name** and **repetition** in the top right section of the screen.
- After the desired information has been completed, press **START ROBOT** button. This sends the equivalent command to the robot.



- Once the participant is ready to start performing the ADL, press **START TIMER** according to the instructions in ***Section 2***.

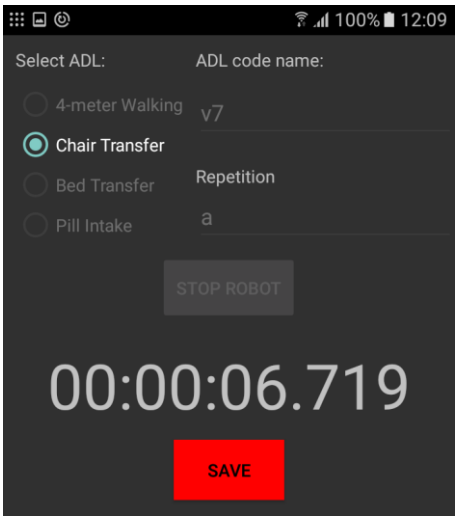
When the START TIMER button is pressed it automatically changes to STOP TIMER (next screen).



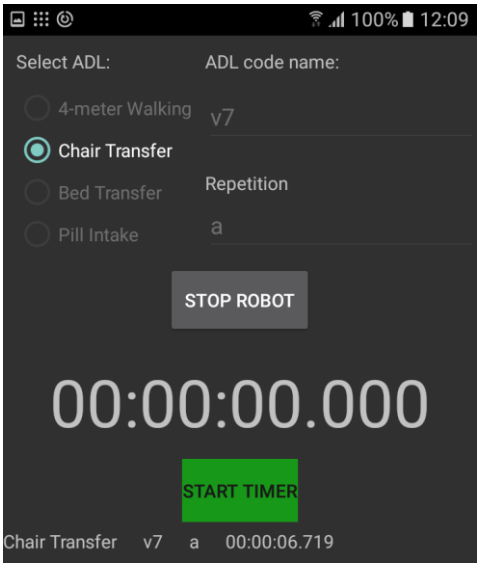
- After the participant completed the ADL, press **STOP TIMER**.

STOP TIMER will freeze the time in the middle of the screen, and the caregiver can take a note of the recorded time.

When the STOP TIMER button is pressed it automatically changes to SAVE (next screen).



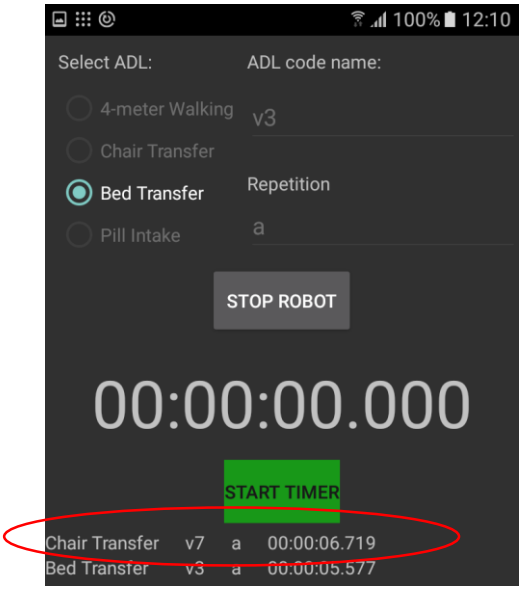
- Press **SAVE** the recorded time.



When SAVE button is pressed, it resets the timer to zero, and also adds the latest recorded time in a list in the lower area of the screen.

This helps the caregiver crosscheck the noted times at the end of each session. Only after SAVE has been pressed can the caregiver send the STOP ROBOT command.

- Press **STOP ROBOT** to proceed to the next recording



Every time an ADL is recorded, it is added in the list below the START TIMER button.

Important Note!

In case **that the timer is**:

a) pressed accidentally or

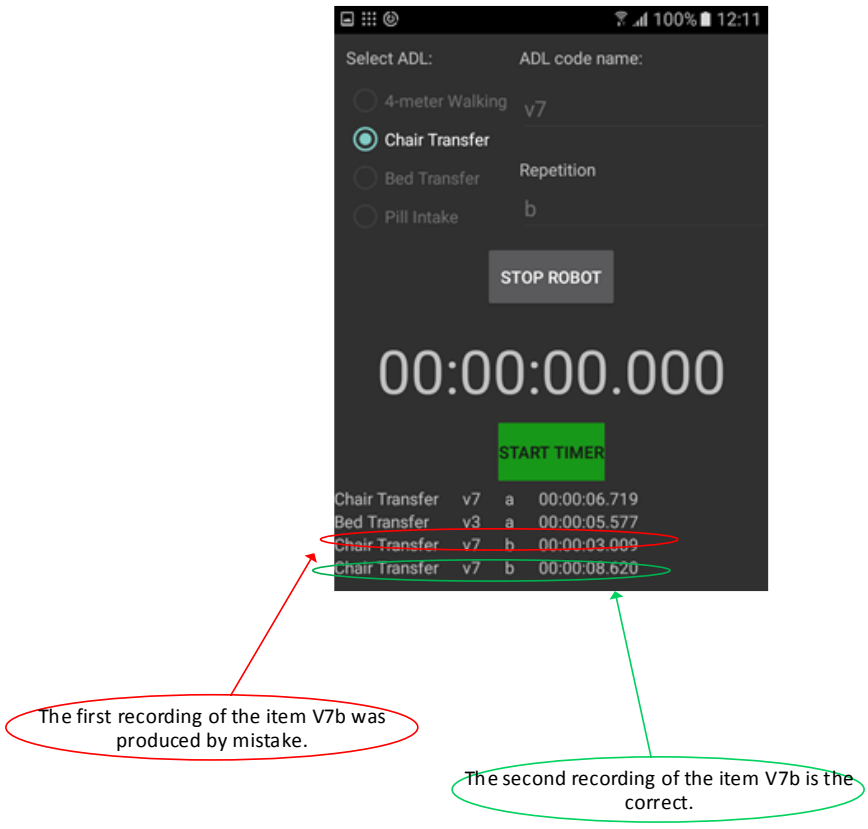
b) had to be stopped by the RA because **something went wrong** with the execution of the ADL (e.g. the participant did not start the ADL when asked or stopped before completing it),

what are the steps to be followed to correctly repeat that ADL?

1. press SAVE (that saves the "wrong value" – e.g in screen below first line in the red)
2. press STOP ROBOT.
3. press START ROBOT
4. Ask the participant to repeat the execution of the ADL and press START TIMER according to the instructions in Section: *Recording and evaluating ADLS*.
5. Press SAVE the value (that saves the "right value" – e.g in screen below second line in the green)
6. Press STOP ROBOT

(The RA can then go on with the rest of the recordings.)

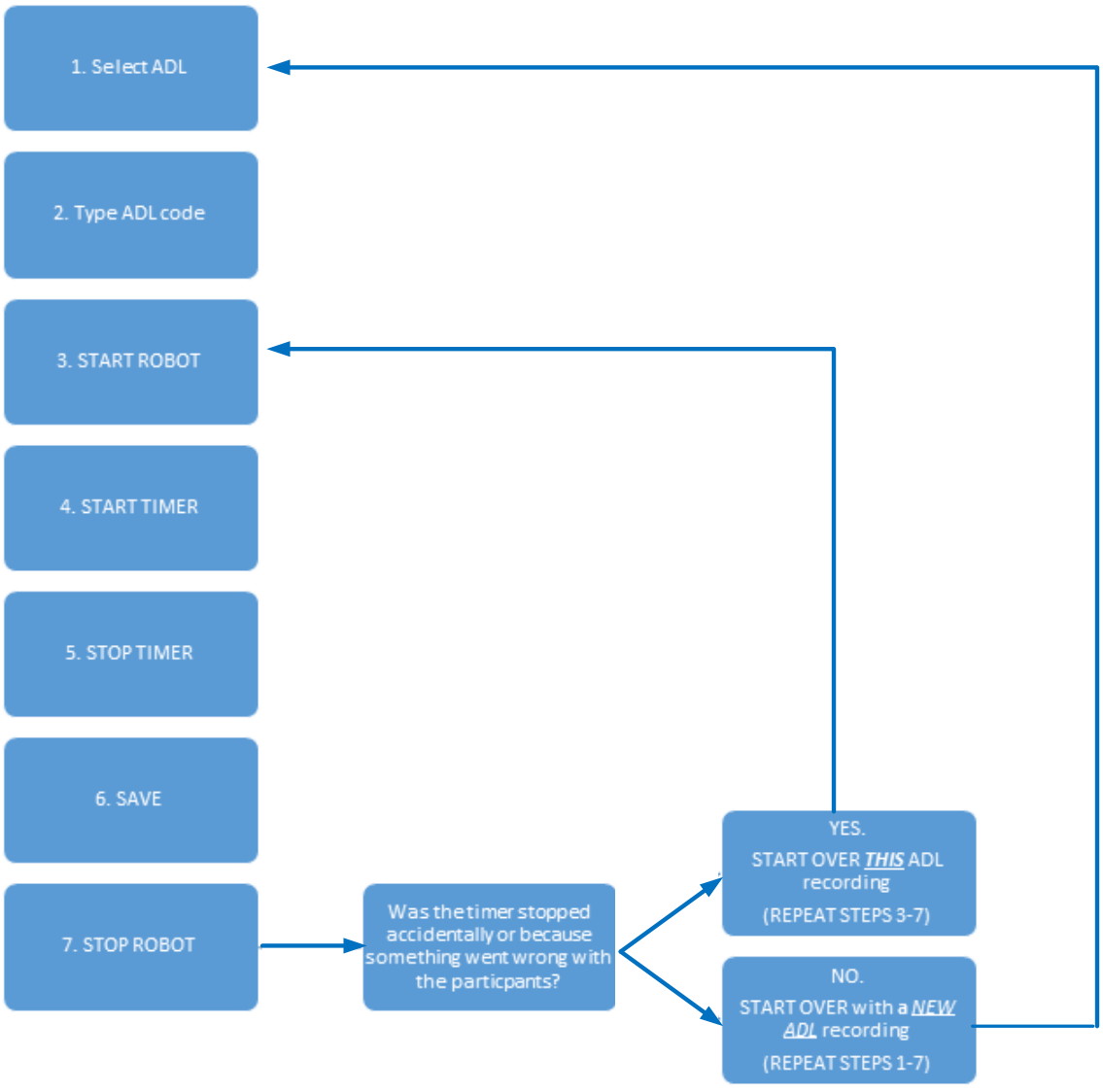
NOTE: As shown below, in this case of one or more failed recordings all values appear in the list of recordings (see Screen below). The RA must **note all the attempts** to record that ADL (with the time recorded) and indicate which one was the correct one.



Other Important notes!

- You should always hear a sound confirming that your command was accepted just like you would using the gamepad. If you don't hear a sound, you will have to use the gamepad to resend the command.
- The research assistant should be careful not to accidentally close the application. If the application is closed, all the recorded times are lost from the Android device. It is recommended to take a note of each recorded time before moving on to the next ADL, to avoid losing data.

The block diagram below summarizes the flow of actions through the application.



5 ROBOT FAILURES OR EMERGENCY

This section will help you react on circumstances that were not planned during the development of the system, but may occur due to various hardware or software defects. The following list contains some of the hazardous circumstances that you might encounter, along with their solution.

Table 4. Robot failures and solutions

ISSUE	SOLUTION
The robot is not moving.	When the robot is commanded to go to a specific location (via the mobile application) and it does not seem to move at all, it should be manually placed in front of the sticker. As soon as the robot is in front of the sticker, the D-Pad Up and D-Pad Down buttons should be pressed, to re-initialize its position, and clear the previously seen obstacles.
The robot is not reacting to gamepad input.	If the robot does not seem to react when gamepad buttons are pressed, make sure that there is enough battery on the gamepad. A good way to check if there is still battery on the gamepad, is to press the "MODE" button two times, and see if there is any light coming from the gamepad.
The gamepad's buttons seem scrambled.	Make sure that the X-Input is selected.
The robot keeps spinning around when a navigation goal is sent.	Clearing the obstacles will most probably solve your problem (D-Pad Down). If this does not solve your problem, please see the first item on this list.
I had to lift the robot and move it manually.	If the robot is lifted from the ground, it is unable to localize. You should follow the instructions on the first item of this list in order to help the robot localize again.
I want the robot to stop moving indefinitely.	There is a **red emergency button** on top of the robot, that will suppress any movement commands, until it is depressed.

6 CONTACT INFORMATION

Name	E-mail	Telephone Number
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	
[redacted]	[redacted]	

APPENDIX IV

Formal caregiver' s manual for the 2nd round of Summative Phase pilot studies at FZ clients' private residences.

ROBOTS IN ASSISTED
LIVING ENVIRONMENTS

UNOBTRUSIVE, EFFICIENT, RELIABLE AND MODULAR SOLUTIONS FOR INDEPENDENT AGEING

Research Innovation Action

Project Number: 643892 Start Date of Project: 01/04/2015 Duration: 36 months

Formal caregiver's manual for the 2nd round of summative phase pilot study at the private residences of FZ clients

Project funded by the European Union's Horizon 2020 Research and Innovation Actions

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1 ROBOT POSITIONS DURING THE PILOTING SCHEDULE

For each private residence different robot positions will be selected.

Table 1 presents ***an example*** of how robot positions can be selected for each phase of the piloting schedule.

Table 1. Piloting schedule for FZ and related robot positions

Day	***Sub scenario***	***Robot monitoring***	***Indicative Robot Positions***	***Comments***
D1 Training Day	***Phase Baseline: Assessment 0.***	Bed transfer	**A**	**A**: This robot position can be in the **bed room** to record bed transfer and pill intake. It should be calibrated for both bed transfer and pill intake. **B**: A position B can be in the living room, calibrated for bed (sofa) transfer and appropriate for chair transfers as well. **C**: This robot position must take advantage of the longest possible path in a house to monitor the 4 meters (or a distance close to this). It could be for example a corridor. **D**: This robot position can be in the kitchen to record chair transfer and pill intake.
		Pill intake	**A**	
		Chair transfer	**B**	
		4-meter walk	**C**	
D2 Study Day	***Phase Baseline: Assessment I***	Bed transfer	**A**	
		Pill intake	**A**	
		Chair transfer	**B**	
		4-meter walk	**C**	
	Phase II (Lunch)	4-meter walk	**C**	
		Chair transfer	**B**	
		4-meter walk	**C**	
		Chair transfer	**D**	
		Pill intake	**D**	
		Bed transfer	**B**	
	Phase III (Dinner)	Chair transfer	**B**	
		Chair transfer	**D**	
		Pill intake	**D**	
		4-meter walk	**C**	
D3 Study Day	***Phase I (Breakfast)***	Bed transfer	**A**	
		Chair transfer	**B**	
		Pill intake	**D**	
		4-meter walk	**C**	

2 COLLECTING GROUND TRUTH VALUES

2.1 Robot monitored ADLs

This section describes the details for recording ground truth values for the ADLs that are monitored by the robot. The instructions in Table 2 take into account how each method works.

Table 2. Ground truth collection for each ADL robot method.

ADL method	Instructions for collecting ground truth
Bed Transfer	This method plays a sound when the system starts recording (**after about 5 seconds**). At that time, the caregiver should start their stopwatch, and stop it when the participant is in a fully upright position.
Pill Intake ADL	This method starts checking for pill movement **after 5 seconds**. Any movement inside a small area around the pill box will be registered as a successful pill intake, thus the caregiver should always place the pill box in the correct position, and then enable the method using the caregiver app.
Sit to Stand ADL	This method has **no special requirements**. The caregiver should start their stopwatch as soon as the participant starts standing up from a sitting position, and stop it when the participant is in a fully upright position. It is recommended that the participant sits to the chair (and then stands up) after the ADL has been started, to help the detection system. It should be noted, that this ADL can be recorded either using the armchair or a table chair.
4 meters walking ADL	This method should always be started **without any feet visible** (participant's or caregiver's). This helps the robot determine easily the moving target. The caregiver should start their stopwatch when the participant starts moving, and stop it when the participant has completed a 4 meters walk. Please note that if the caregiver is inside the robot's field of view and stays completely still, it won't negatively affect the method's performance. The caregiver should use floor tiles to measure and mark a distance of 4 meters.

2.2 Smart home

ADL method	Instructions for collecting ground truth
TV watching	When the user sits on the predefined chair and the TV is activated the caregiver writes down the time. If the chair is close to the TV set he/she indicates *true_event*. If the char is not close to the TV set he/she indicates *false_event*. The TV must be active for ~10 minutes before an event is logged. When a chair is moved from *close* to *not_close* to the TV set and vice versa a time duration of 10sec must pass before e new test can be initiated.
Going out	Going out the room of going in the room ground truth is extracted by the questionnaire the user fills.

3 ROBOT CONTROL VIA THE GAMEPAD

This section provides the guidelines on how to control the robot via the gamepad (see Table 2 below).

Table 3. Gamepad controls

SIDE GAMEPAD VIEW

TOP GAMEPAD VIEW

D-pad Up	Initialize Robot Position (in front of the sticker)
D-pad Down	Clear Obstacles on Robot's Map
LB	Stop robot's movement (for as long as it's pressed)
LB+LeftStick	Control robot's linear velocity.
LB+RightStick	Control robot's angular velocity.
RT+RightStick [Pressed]	Enable Auto-Docking [1] (charging)
Start	Send report for the latest participant
Back	Cancel navigation goal
X	Start 4 meter walking ADL
RT+X	Stop 4 meter walking ADL
A	Start Chair Transfer ADL
RT+A	Stop Chair Transfer ADL
B	Start Bed Transfer ADL
RT+B	Stop Bed Transfer ADL
Y	Start Pill Intake ADL
RT+Y	Stop Pill Intake ADL
RT +RB **OR** RT+D-pad Left	Robot position 2[2]
RT+D-pad Right **OR** RT+ LeftStick [Pressed]	Robot position 1[2]

[1] In this function the robot should be placed in front of the docking station, keeping a distance of at least half a meter, but no more than a meter.

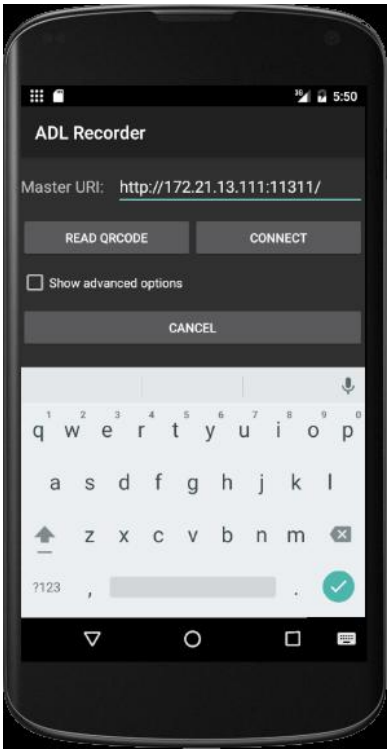
[2] Up to 4 robot positions can be added depending on whether autonomous navigation will be used or not. This will be adapted for each residence, depending on the residence's design.

Important notes!

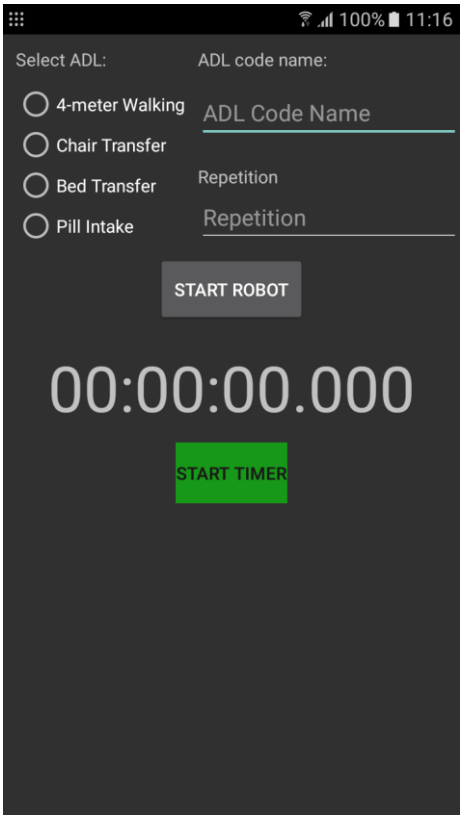
- You will always hear a sound that confirms that your command was accepted.
- If you don't hear a sound, you can try sending your desired command again.
- Back button stops the robot from moving until another command is sent to it.
- LB button stops the robot for as long as the button is pressed.
- All combinations of buttons that include RT, should be used in the following order:
    - Press and keep RT
    - Press the other button
    - Release the other button
    - Release RT
- Always make sure that the gamepad's input is switched to 'X' (and not 'D').
- Bed Transfer and Pill Intake ADLs need about 5 seconds to initialize.
- In case of a failure in the recording, the caregiver has to take a note of the failed recording (like they would do with a successful one) and repeat the ADL by following the normal procedure. (The failed recording should be included in the RA report).

4 RECORDING ADLS VIA THE MOBILE APPLICATION

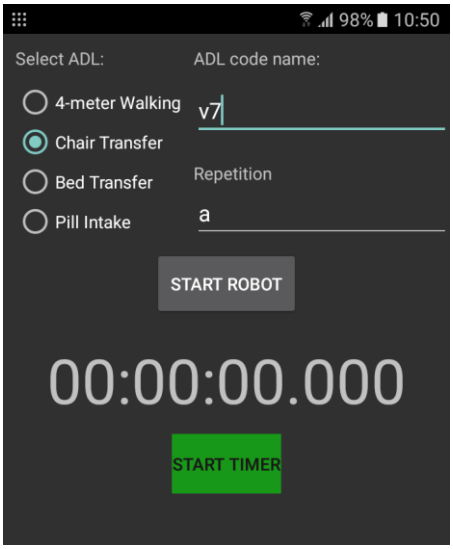
The use of the Android ADL Recorder aims to reduce the difficulties the caregivers face while recording ADLs, and at the same time reduce human errors.



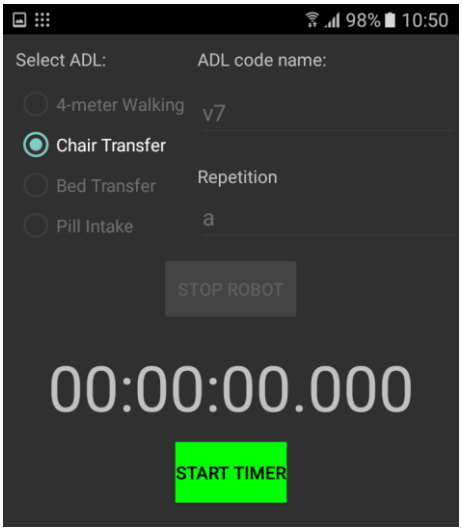
The application starts in the Connection Screen where the caregiver has to ensure that the Master URI is set to http://192.168.2.216:11311/. This address has to be set only the first time, as it is then saved automatically. Before pressing connect, the caregiver should **make sure that the device is connected to the RADIO-dedicated network**.



When connect is pressed and given that the connection was successful, the **Main Screen** is shown. This is where the caregiver can send commands to the robot and also use the built-in timer to record the ground truth for each ADL. The process is completely streamlined, leaving no room for alternative choices.

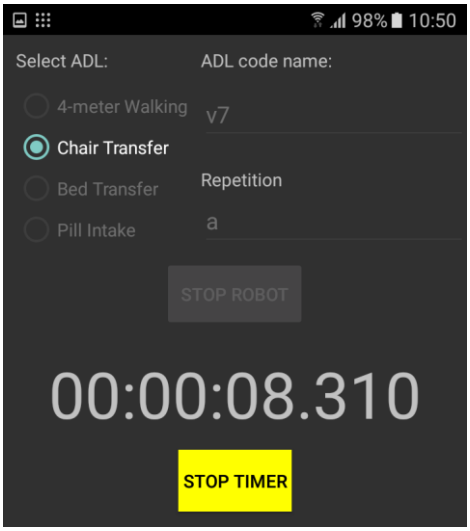


- The caregiver has to **select an ADL** from the top left section of the screen, then **type an ADL code name** and **repetition** in the top right section of the screen.
- After the desired information has been completed, press **START ROBOT** button. This sends the equivalent command to the robot.



- Once the participant is ready to start performing the ADL, press **START TIMER** according to the instructions in ***Section 2***.

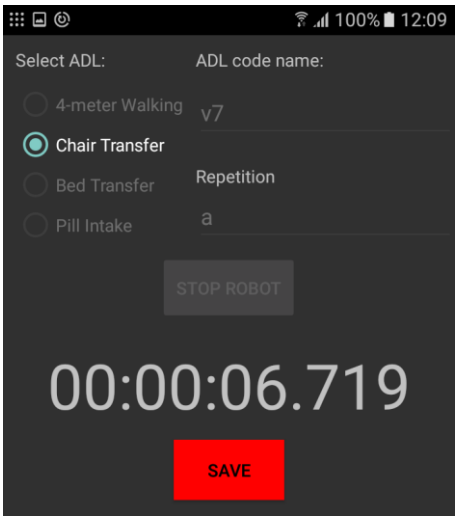
When the START TIMER button is pressed it automatically changes to STOP TIMER (next screen).



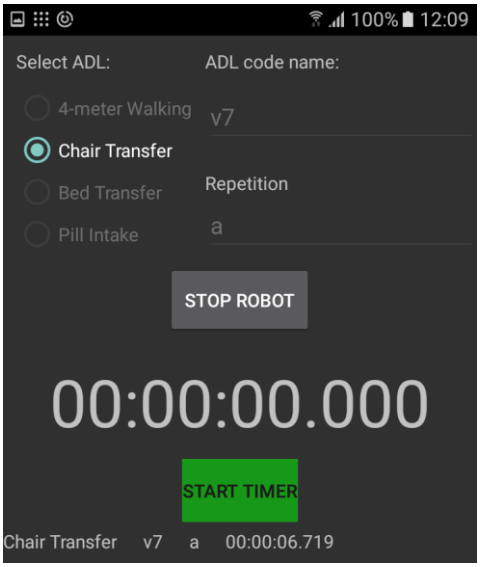
- After the participant completed the ADL, press **STOP TIMER**.

STOP TIMER will freeze the time in the middle of the screen, and the caregiver can take a note of the recorded time.

When the STOP TIMER button is pressed it automatically changes to SAVE (next screen).



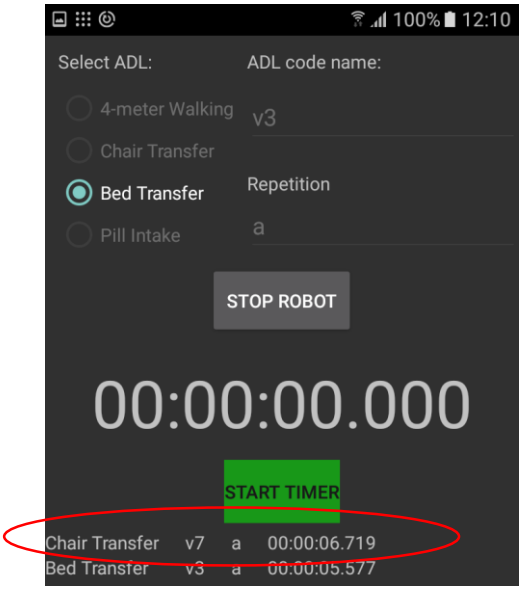
- Press **SAVE** the recorded time.



When SAVE button is pressed, it resets the timer to zero, and also adds the latest recorded time in a list in the lower area of the screen.

This helps the caregiver crosscheck the noted times at the end of each session. Only after SAVE has been pressed can the caregiver send the STOP ROBOT command.

- Press **STOP ROBOT** to proceed to the next recording



Every time an ADL is recorded, it is added in the list below the START TIMER button.

Important Note!

In case **that the timer is**:

a) pressed accidentally or

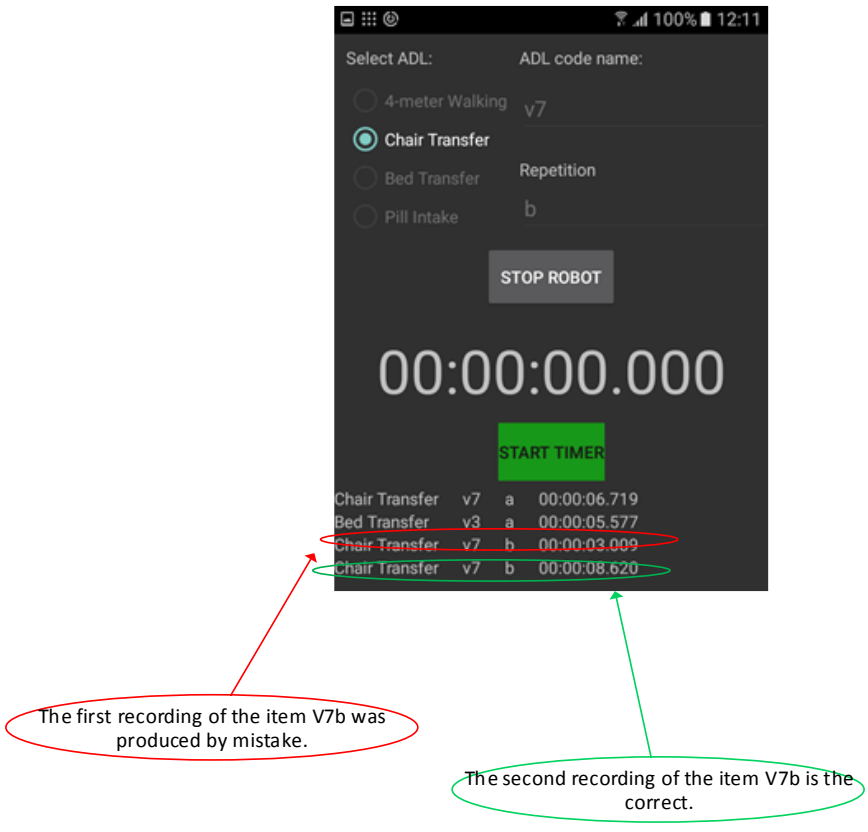
b) had to be stopped by the RA because **something went wrong** with the execution of the ADL (e.g. the participant did not start the ADL when asked or stopped before completing it),

what are the steps to be followed to correctly repeat that ADL?

1. press SAVE (that saves the "wrong value" – e.g in screen below first line in the red)
2. press STOP ROBOT.
3. press START ROBOT
4. Ask the participant to repeat the execution of the ADL and press START TIMER according to the instructions in Section: *Recording and evaluating ADLS*.
5. Press SAVE the value (that saves the "right value" – e.g in screen below second line in the green)
6. Press STOP ROBOT

(The RA can then go on with the rest of the recordings.)

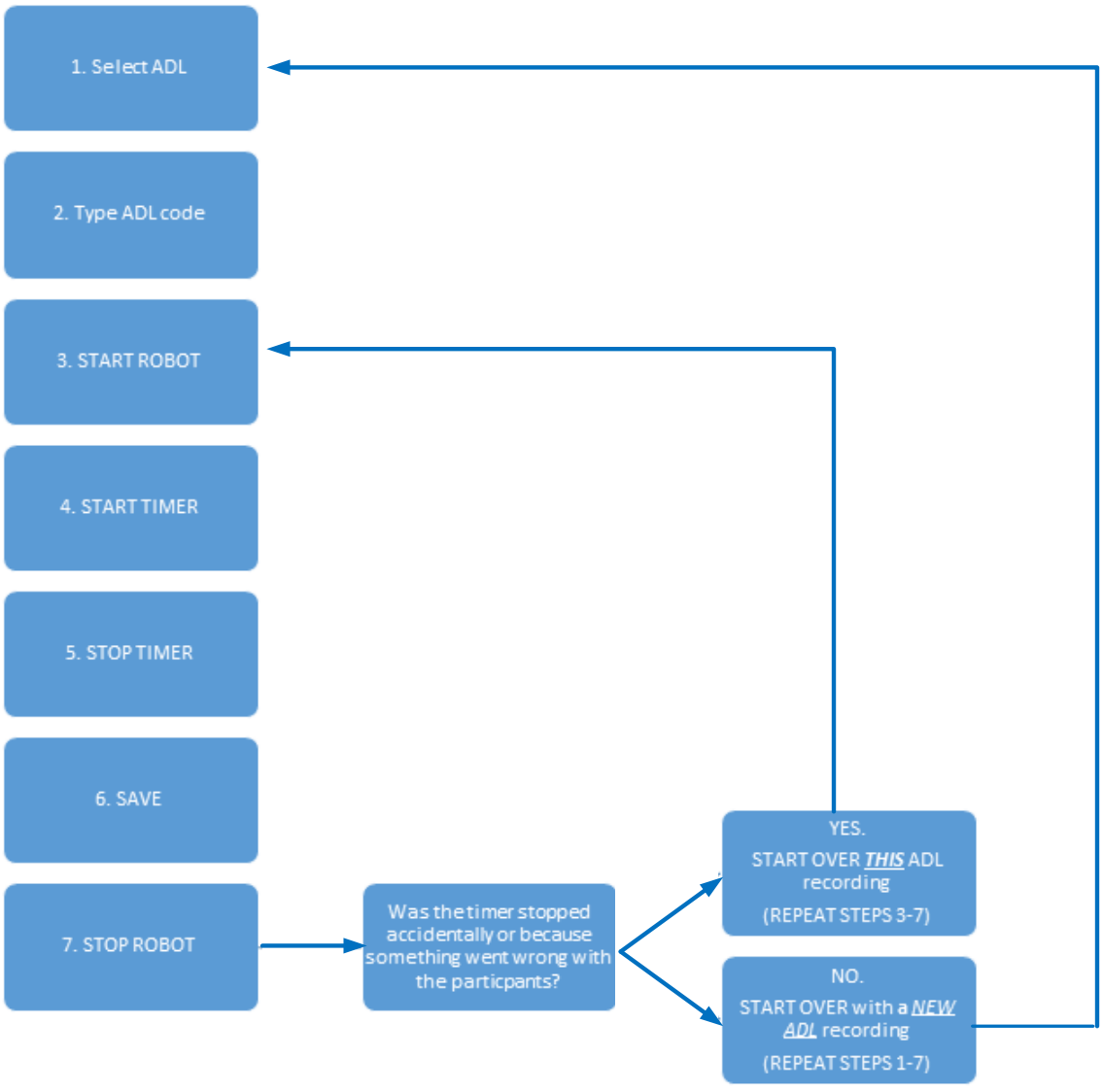
NOTE: As shown below, in this case of one or more failed recordings all values appear in the list of recordings (see Screen below). The RA must **note all the attempts** to record that ADL (with the time recorded) and indicate which one was the correct one.



Other Important notes!

- You should always hear a sound confirming that your command was accepted just like you would using the gamepad. If you don't hear a sound, you will have to use the gamepad to resend the command.
- The research assistant should be careful not to accidentally close the application. If the application is closed, all the recorded times are lost from the Android device. It is recommended to take a note of each recorded time before moving on to the next ADL, to avoid losing data.

The block diagram below summarizes the flow of actions through the application.



5 ROBOT FAILURES OR EMERGENCY

This section will help you react on circumstances that were not planned during the development of the system, but may occur due to various hardware or software defects. The following list contains some of the hazardous circumstances that you might encounter, along with their solution.

Table 4. Robot failures and solutions

ISSUE	SOLUTION
The robot is not moving.	When the robot is commanded to go to a specific location (via the mobile application) and it does not seem to move at all, it should be manually placed in front of the sticker. As soon as the robot is in front of the sticker, the D-Pad Up and D-Pad Down buttons should be pressed, to re-initialize its position, and clear the previously seen obstacles.
The robot is not reacting to gamepad input.	If the robot does not seem to react when gamepad buttons are pressed, make sure that there is enough battery on the gamepad. A good way to check if there is still battery on the gamepad, is to press the "MODE" button two times, and see if there is any light coming from the gamepad.
The gamepad's buttons seem scrambled.	Make sure that the X-Input is selected.
The robot keeps spinning around when a navigation goal is sent.	Clearing the obstacles will most probably solve your problem (D-Pad Down). If this does not solve your problem, please see the first item on this list.
I had to lift the robot and move it manually.	If the robot is lifted from the ground, it is unable to localize. You should follow the instructions on the first item of this list in order to help the robot localize again.
I want the robot to stop moving indefinitely.	There is a **red emergency button** on top of the robot, that will suppress any movement commands, until it is unpressed.

6 CONTACT INFORMATION

Name	E-mail	Telephone Number
[redacted] **(technical support)**	[redacted]	[redacted]
[redacted] **(pilot study methods support)**	[redacted]	[redacted]
[redacted] **(technical support)**	[redacted]	[redacted]
[redacted] **(technical support)**	[redacted]	[redacted]
[redacted] **(technical support)**	[redacted]	[redacted]
[redacted] **(pilot study methods support)**	[redacted]	[redacted]

APPENDIX V

RADIO installation guide.

RADIO Installation Guide

George Stavrinos / NCSR Demokritos

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1 REQUIREMENTS

In order to be able to install the robot in a new house, you will need a machine with the following two capabilities:

- SSH
- ROS

The instructions in the following sections should work in any machine under any operating system that fulfills the above requirements, but it is recommended to use any flavour of Ubuntu 14.04 and above. Beware, some of the instructions that follow include information only for the recommended operating system.

For more information on SSH, please visit:

- Linux/Mac: `https://www.ssh.com/ssh/command/`
- Windows: `http://www.putty.org/`

For more information on ROS, please visit:

- All platforms: `http://wiki.ros.org/`

All the instructions provided in this document assume that you have set the following environment variables as listed:

- ROS_IP=<MACHINE IP>
- ROS_MASTER_URI=http://<ROBOT IP[TODO]>:11311
- ROS_HOSTNAME=<MACHINE HOSTNAME>

Under Linux, in order to avoid having to set those environemt variable everytime, in your /.bashrc file, you can add (or replace older values with) the following lines:

```
export ROS\_IP=<MACHINE IP>
export ROS\_MASTER\_URI=http://<ROBOT IP[TODO]>:11311
export ROS\_HOSTNAME=<MACHINE HOSTNAME>
```

Regardless of your operating system, in order to find out your hostname, just type in a terminal:

```
hostname
```

Replace <MACHINE HOSTNAME> with the returned value.

Assuming you are already connected to the RADIO provided LAN, in order to find out your IP type in a terminal:

- Linux/Mac:

  ```
  ifconfig
  ```

- Windows:

  ```
  ipconfig
  ```

Replace <MACHINE IP> with the returned value.

For Linux and Mac, make sure that your /etc/hosts file, includes the following lines:

```
<MACHINE IP> <MACHINE HOSTNAME>
<ROBOT_IP[TODO]> turtlebot-ncsr-2
<MAIN CONTROLLER IP[TODO]> main-controller
```

For Windows users, the equivalent file is \WINDOWS\system32\drivers\etc\hosts.

When you are instructed to run a command on the robot, you will have to first connect to it via ssh. The robot's credentials are:

- Username: turtlebot
- Password: ros

When you are instructed to run a command on the main controller, you will have to first connect to it via ssh. The main controller's credentials are:

- Username: pi
- Password: raspberry

2 ROBOT CONTROLS

Top gamepad view

Side gamepad view

Button	Action
D-pad Up	Initialize Robot Position (in front of the AR Marker)
D-pad Down	Clear Obstacles on Robot's Map
LB	Stop Robot's Movement (for as long as it's pressed)
LB+LeftStick	Control Robot's Linear Velocity
LB+RightStick	Control Robot's Angular Velocity
RT+RightStick[Pressed]	Enable Auto-Docking (charging)
Start	Send report for the latest participant
Back	Cancel Navigation Goal
X	Start 4 meter walking ADL
RT+X	Stop 4 meter walking ADL
A	Start Chair Transfer ADL
RT+A	Stop Chair Transfer ADL
B	Start Bed Transfer ADL
RT+B	Stop Bed Transfer ADL
Y	Start Pill Intake ADL
RT+Y	Stop Pill Intake ADL
RT+RB	Bed transfer position
RT+D-pad Right	Chair transfer position
RT+D-pad Left	4 meters walk position
RT+LeftStick[Pressed]	Pill intake position

Important Notes!

- You will always hear a sound that confirms that your command was accepted.
- Back button stops the robot from moving until another command is sent to it.
- LB button stops the robot for as long as it's pressed.
- All combinations of buttons that include RT, should be used in the following order:
  1. Press and keep RT
  2. Press the other button
  3. Release the other button
  4. Release RT
- Always make sure that the gamepad's input is switched to 'X' (and not 'D').

3 MAPPING A NEW HOUSE

Firstly we will see the commands that have to be executed in order to start the mapping procedure, and then we will have an explanation for each one of them.

```
rosnode kill /amcl
rosnode kill /move_base
rosnode kill /map_server
roslaunch turtlebot_navigation gmapping_radio_demo.launch
```

Explanation of commands:

- The localization procedure runs on boot, so we will have to kill it first.
- Move base runs on boot, so we will have to kill it because we will run it again in a following command.
- Map server runs on boot, but since we need to create a new map, we will have to kill it.
- Run the mapping procedure (that also starts a new move base process).

In order to create an effective map for the house, it is required to:

- Move slowly.
- Rotate the robot slightly in place, just to cover hard to see corners.
- Try not to pass from the same place twice.

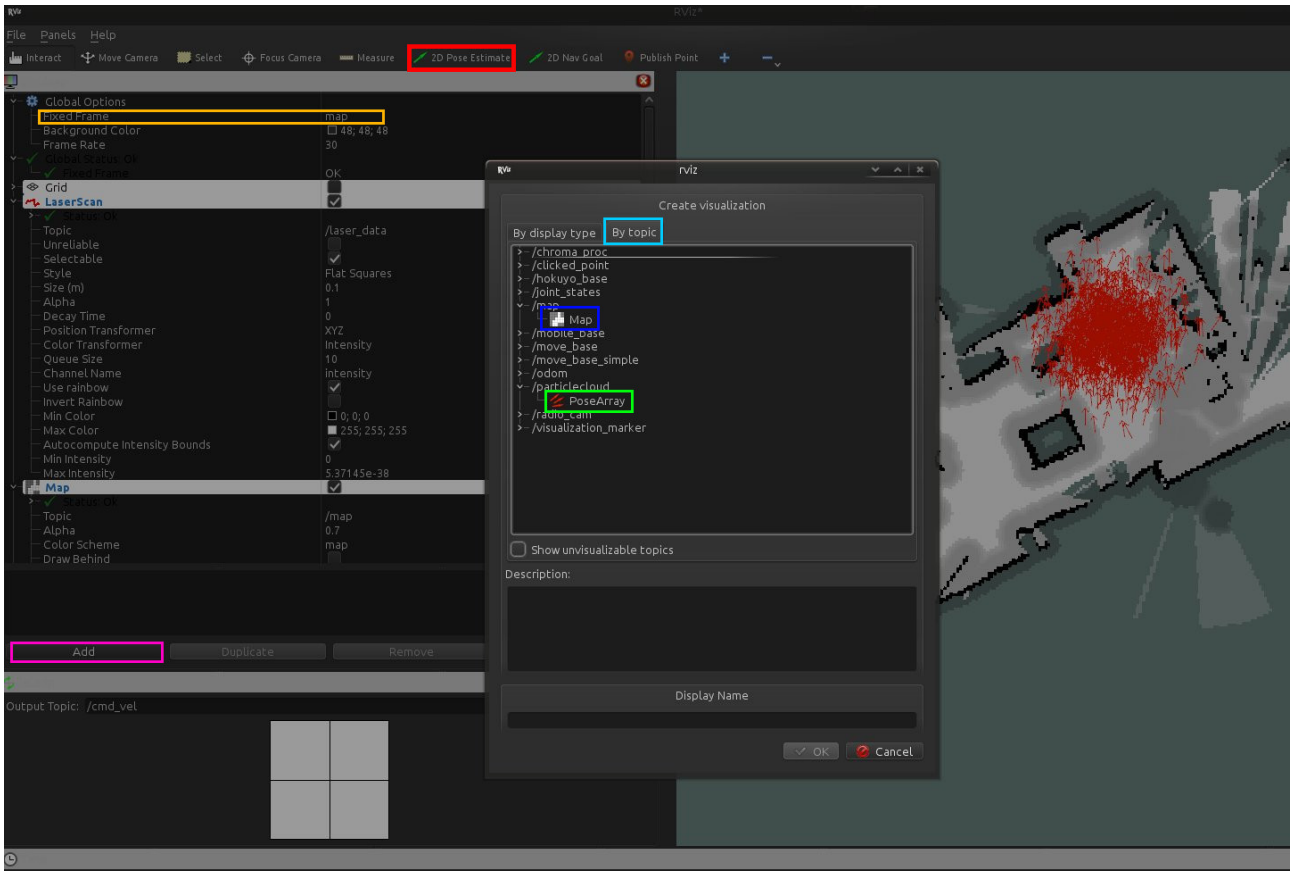
After the robot has been teleoperated through the whole house (or the part of the house that is going to be used by RADIO) it is time to save the map by running the following commands on the robot (in a separate terminal):

```
roscd turtlebot_navigation/maps
rosrun map_server map_saver -f house
```

The map has now been created. We can close all the running processes, and reboot the robot.

4 LOCALIZING THE ROBOT

4.1 USING RVIZ



In order to localize the robot using rviz, you need to follow the steps below:

1. Run rviz by running in a terminal on your machine:

   ```
   rosrun rviz rviz
   ```

2. Set the Fixed Frame to map (highlighted with orange)
3. Add the map by clicking Add (highlighted with pink), then By topic (highlighted with cyan) and then Map (highlighted with blue)
4. Add the robot pose by clicking Add (highlighted with pink), then By topic (highlighted with cyan) and then PoseArray (highlighted with green)
5. Set the robot's position as precisely as possible by using the 2D Pose Estimate button (highlighted with red) and then clicking on the desired location on the map. By holding and rotating the cursor, you can also choose the robot's orientation.
6. Rotate the robot in place using the gamepad, to help the robot localize even better.

4.2 USING THE AR MARKER

This method requires the AR Marker to be set up. This is a process described later in this document.
In order to localize using the AR Marker:

1. Place the robot in front of the AR Marker.
2. Press the corresponding AR Marker localization button on the gamepad.

5 SETTING ROBOT ADL POSITIONS

Make sure that the robot is localized before proceeding. With the robot correctly localized we can teleoperate it to the desired locations to check if they are suitable. Warning: Never place the robot in a desired location by lifting it off the ground. If you have to, make sure to localize it again.

5.1 SELECTING THE POSITIONS

The robot positions that have to be set along with their specifications, are the following:

- 4-meter walking ADL: This ADL requires a corridor or open space, where at least four meters are visible by the robot's laser scanner (180°FOV)
- Bed Transfer ADL: Ensure that the person of interest, when stood up, fits the camera's frame with at least 20cm gap between the top of their head and the top of the frame.
- Pill Intake ADL: Ensure that there is direct contact with the pill's position from the camera.
- Sit to Stand ADL: Ensure that the person of interest, when stood up, fits the camera's frame with at least 20cm gap between the top of their head and the top of the frame.

The following pages show some positions that have been used in past RADIO installments. Please read each photo's description.

This photo shows the bed transfer position. The robot is too close to the bed, so the camera's stand have been shifted up, in order to fit the person in the frame when stood up. Generally, the robot should be further away from the bed if possible.

This position of the robot is an effective choice because it can be used for two ADLs: Pill Intake and Sit to Stand. The Pill Intake's position is marked with a red rectangle. Sit to Stand should be recorded from the sofa on the right of the small table.

This is another good position choice, because it combines the Pill Intake and the 4-meter Walking ADLs. The pill should be placed inside the marked rectangle, and the 4-meters walking can be recorded in the corridor on the right of the small table.

5.2 CHECKING THE POSITIONS

Now that we know the requirements for the position of each ADL, let's see how we can check each selected position.

- 4-meters walking: This ADL does not require a machine to check, since the only thing that has to be done in order to ensure the effectiveness of the recording, is to make sure that there is a a straight line (or even a curve) that is always visible by the robot's laser scanner and is at least four meters long.
- Pill Intake: See the robot's camera by running in a terminal on your machine:

  ```
  rqt_image_view /radio_cam/rgb/image_raw/compressed
  ```

  Adjust the selected position accordingly.
- Bed Transfer: See the robot's camera by running in a terminal on your machine:

  ```
  rqt_image_view /radio_cam/rgb/image_raw/compressed
  ```

  Adjust the selected position accordingly.
- Sit to Stand: See the robot's camera by running in a terminal on your machine:

  ```
  rqt_image_view /radio_cam/rgb/image_raw/compressed
  ```

  Adjust the selected position accordingly.

5.3 SAVING THE POSITIONS

When you are happy with the selected ADL position, you can save it by following the steps below:

1. See the robot coordinates by running in a terminal on your machine:

   ```
   rostopic echo /amcl_pose
   ```

2. Take a note of the position.x, position.y, orientation.z and orientation.w coordinates.
3. In a terminal on the main controller run:

```
roscd radio_node_manager_main_cotroller/config/
```

4. In the same terminal edit the parameters.yaml file and add the coordinates to the equivalent variables.

6 CONFIGURING ADLS

Upon selecting the positions, some ADL methods still require some configuration. The ADL methods that need additional actions are listed below:

- Pill Intake: You need to move and resize the detection rectangle so that it covers the position of the pill inside the camera frame. You can also adjust the CUPTHRESHOLD and CUPTHRSCOUNT to make the method more or less sensitive.
- Bed Transfer: You need to set the left and right limits of the bed, so that there is enough room for a person to be stood up next to the bed, and still be inside inside the limits. It is recommended to use at least 1 meters from each side of the bed. You also need to adjust the upper limit, so the head of the person in interest when stood up is over it. You can also adjust the SENSITIVITY to make the method more or less sensitive.

In order to configure all the above, you need to run the following commands on the robot (each command in a separate terminal):

```
roslaunch motion_analysis new_configuration.launch
rosservice call /motion_analysis/node_state "command: 11"
```

Also, run the following command on your machine:

```
rqt_image_view /motion_analysis/motion_analysis_viz/compressed
```

In the terminal that you ran the first command on the robot you can now adjust the limits by following the onscreen instructions. If you save your current configuration but need to come back later to it, instead of the first command on the robot run:

```
roslaunch motion_analysis edit_current_configuration.launch
```

and run the rest of the commands as described earlier.

In either case, when done, close all running processes and reboot the robot.

7 SETTING UP THE AR MARKER

In order to set up the AR Marker, following the steps below:

1. Stick the Marker above the charger in the same height as the robot's camera.
2. Make sure the robot is localized.
3. Teleoperate the robot in front of the sticker.
4. Run in a terminal on the robot:

```
rosservice call /marker_mapping_node/save_maker "id: [] filename: ''"
```

The AR Marker is now set up. You can now kill all running processes and restart the robot.

Correct charger and AR Marker position

8 SETTING THE 'GUIDE ME' POSITIONS

In order to set the 'Guide Me' positions, thus the rooms of interest of the house, follow the steps below:

1. In a terminal on the main controller run:

```
rosrun radio_home_configuration configure.py
```

2. Follow the simple on screen instructions.
3. Reboot the main controller when you have finished.

When you need to enter the coordinates of the room:

1. Make sure the robot is localized.
2. Teleoperate the robot to the room, and place it in the desired position.
3. See the robot (thus room) coordinates by running in a terminal on your machine:

```
rostopic echo /amcl_pose
```

4. Take a note of the position.x, position.y, orientation.z and orientation.w coordinates.

9 DEPLOYMENT STEPS

The inventory in each deployment comprises:

1. the RADIO Robot
2. the RADIO Smart Home Pack
3. the RADIO Raspberry Rack
4. an Android Tablet
5. a Joystick

During the installation time only a PC with Linux (preferably) is also required.

The following table presents the steps that should be followed in each deployment, along with the estimated time for each task and relevant details or the corresponding section of this guide when applicable.

Step	Estimated time (min)	Details
Setting up Raspberry Rack and RADIO network	30	Decide on appropriate position for Raspberry Rack. Choose a place offering good Wifi connectivity in all interesting rooms.
Mapping	30	Section 3
Setting up docking station	30	Section 7 -Decide on appropriate position, setup docking station and QR, test docking procedure.
Setting Robot ADL positions	120	Section 5 -Decide on appropriate positions. Test Wifi connectivity. Test autonomously moving between initial position (docking station) and all positions and moving from one position to another. Test multiple rounds to ensure repeatability.
Configuring ADLs	120	Section 6-Use motion analysis configuration tool (executing on laptop) to configure motion analysis methods. Test by getting in and out of bed and using the pill box with observing the configuration tool. If appropriate motion limits cannot be found, different positions might need to be found (repeat ”Setting Robot ADL positions”)
Setting up RADIO Home sensors	40	Decide on appropriate position for sensors. Install and test sensors. Test connectivity to Rack and to S&C cloud server.
Setting up RADIO BLE beacons and ”Guide me” tags	40	

TABLE 1: RADIO deployment steps.

10 CONTACT INFORMATION

Name	E-mail	Telephone Number
[redacted]	[redacted]	[redacted]

19