3.1 Publishable summary

The HOBBIT project envisions a robotic product that will enable **older people to feel safe and stay longer in their homes** by using new technology including smart environments (ambient assisted living - AAL). The main goal of the robot is to provide a "feeling of safety and being supported" while maintaining or increasing the user's feeling of self-efficacy (one's own ability to complete tasks). Consequently, the functionalities focus on emergency detection (mobile vision and AAL), handling emergencies (calming dialogues, communication with relatives, etc.) as well as fall prevention measures (keeping floors clutter-free, transporting small items, searching and bringing objects, and reminders). Moreover, high usability, user acceptance as well as a reasonable level of affordability are required to achieve a sustainable success of the robot.

In order to achieve the goal of high **user acceptance**, the core element of the HOBBIT project is the concept of **Mutual Care**. Mutual Care is an interaction design framework for assistive robots to facilitate relationships with their users. Its main idea is the mutual understanding of each other's needs. Thereby, the robot learns the habits and preferences of the user to adapt its communication and behaviour. At the same time, the user adapts to the robot's intellectual and physical capabilities. In Mutual Care, the focus is on the conjoint adaptation and on strategies that follow the dynamics of real social relationships. Similar to a puppy, the Mutual Care robot and its owner adapt to each other when starting a new life together.

The theoretical framework for Mutual Care has been derived from a threefold basis. First, the sociological paradigm of “social roles” helps to understand the process of embedding robots within the social network of our target group. Second, the “helper theory” describes the social dynamics of mutual-aid groups. And third, the concept of “mental models” from cognitive psychology guides us to develop user-adaptive behaviour repertoires for HOBBIT. Based on this interdisciplinary framework Mutual Care is designed to work platform-independently and could be used with all other robot installations.

By mid-term of the project, a first version (PT1) of HOBBIT has been realized and evaluated in a first round of user trials. The results will be reported further below. Based on the received feedback, a new prototype PT2 is being designed and is going to be evaluated in another series of trials in the final project period. As with PT1, also PT2 the Human-Robot Interaction with HOBBIT will be evaluated in terms of usability, user acceptance, and affordability.

Overall the main evaluation goal is to explore the following main question: Do older adults experience HOBBIT and its Mutual Care aspects as a suitable mean to maintain independent living in their private household? In order to make this overall guiding research question operational and measurable in empirical research, we developed user trials in three countries and structured the findings into three main evaluation concepts: usability, user acceptance, and affordability.

The main work within the frame of WP1 of year two was organization and **completion of the scenario-based user trials with PT1**. These took place in Austria at AAF, in Greece at FORTH and in Sweden at ULUND. The trials with a total of 49 PU and 35 SU followed a clear sequence of six tasks, and participants were divided into a Mutual Care and a non-Mutual Care condition, in order to examine and compare differences between the groups.

Results were gained from questionnaires, observation protocols and interviews with the participants during and after the trials. The results from all partners were encoded and analyzed by means of SPSS.

The most **important results** of the PT1 trials related to the three categories were:

Usability

- 49% of PUs found the robot easy to use and 46.9% felt rather confident in using PT1
- Voice commands and touch screen were liked best as operation mode by PUs
- In general, the usability of the MMUI has been confirmed by the PUs

Acceptance

- Users in the Mutual Care group perceived the support in the tasks significantly as more mutual than users in the control group (r=.357/p=.013).
- A pick up from floor-function was most important for PUs (52.2%), compared to picking up objects from the table or a high shelf.
- 77.6% of the PUs found a transporting functionality important.
- The implemented emergency dialogue was rated very acceptable by users in terms of length and speed.
- 65.8% of PUs fulfilling the inclusion criteria found it very important to use HOBBIT as an aid to stand up from the floor (after a fall).
- Overall, users with a mobility impairment found PT1 to be more helpful in their home than PUs without a mobility impairment (p=.001).
- In terms of higher acceptance through entertainment offers, memory training, music, audio books, and fitness instructions were most important for older users.
- Among SUs liking the design was significantly correlated with imagining to buy the robot for one's relative (r=.405/p=.020) and renting it (r=.361/p=039).

Affordability

- When asked directly, 63.2% of the PUs could rather not or not at all imagine buying such a robot (40.8% "not at all").
- Yet 77.6% of PUs could imagine to rent a HOBBIT (49% "very much"; 28.6% "rather").
- SUs also preferred a renting option (22.4% "very much"; 26.5% "rather").

Conclusively, the findings from PT1 trials pointed towards

- necessary changes in the dialogues of the robot,
- changes in speed of the robot,
- design of HOBBIT,
- a possible renting-business model for a future product,
- and extension of speech commands.

It was furthermore analyzed which functionalities are more important to users than others, as an indicator for PT2 scenarios. While pick up from floor and rise from floor obtain high priority, functions such as a walker or grasping from a table are ranked medium resp. low. Consequently, the project will aim to provide the high priority functions first.

The **Mutual Care hypotheses** were tested and could be confirmed, underlining the basic dynamics of Mutual Care to be working. In the task, where the robot is asked to bring the object and the user had to help, users perceived this reciprocity, the basic element of Mutual Care. And the effect had endurance. The Mutual Care robot was perceived as easier to use, users perceived that less training was needed before get going with the robot, and users did not want to miss the "return of favour" feature.

Based on these findings, the **PT2 user trials** at the end of the project will study how a Mutual Care relation could improve user acceptance. For PT2 the elaboration of Mutual Care focuses on three central questions:

1. How does HOBBIT learn habits of the user and how does it apply reminders them?
2. How can HOBBIT learn behavior and preferences of the user, and how does it adapt and respond to them?

3. What can be measured to obtain evidence if and how HOBBIT can extend the period of user staying at home?

The answer for the first two questions can be found in the framework of Mutual Care itself which is based on the paradigm of "social roles". The functional role behavior can always be influenced directly by the user to ensure a maximum of control over the robot (e.g. medication or waking time). Additionally HOBBIT will ask the user regularly about if its behaviour is perceived as too obtrusive and adapts its behaviour accordingly to her answers (e.g. if the user prefers a butler-like behavior, then the robot communicates in a polite and not too amicable style).

For the third question we assume that Mutual Care can extend the user's period of staying at home by maintaining her **self-efficacy** and the **perceived safety** in her home. These two aspects will be investigated in PT2 using

1. Interviews & Questionnaires: before, at the end and weeks after the trial for primary and secondary users.
2. Cultural Probing: the user observers and judges the safety issue.
3. Logging Data: recording interaction events, and their progressions.

These questions are the basis for developing the **scenarios for PT2**. The detailed planning and designing of PT2 trials has been started. Mutual Care parameters are modelled based on social role, which spans from tool-like over a butler to a companion. Becoming increasingly more social is implemented by increasing the presence of HOBBIT close to the user and increasing the number of interactions with the user. PT2 will adapt its behavior depending on the user's responses. In this way we want to find out what preferences users have to obtain high acceptance.

The older **person and HOBBIT communicate and interact in several different ways**, using speech, text, gestures and a touchscreen depending on the preferences of the individual user. A framework for this communication has been developed and reported in deliverable D2.1 and the implementation of the multi-modal user interface has been delivered for integration in PT1.

Systems for Automatic Speech Recognition and Text-To-Speech that support necessary languages (English, German, Greek and Swedish) have been implemented as speech is an important way of communication according to the results from the workshops with users. The UI was successfully used and evaluated in the PT1 trials. During the trials work started on the advanced user interface for PT2 and improvements on ASR performance under varying distant speech conditions. Observations from trials were used to guide the laboratory testing of microphones and speech recognition engines, comparison with reports on state of the art and contacts to related projects in order to find the optimum balance for PT2. The UI was extended with more entertainment related functions, the physical activity and other new interaction for PT2.

A new appearance **design** has been developed **for PT2** based on the results from the PT1 user trials. The PT2 design has more ergonomic positions of the touchscreen and the tray, a solution for improved usability for the "learn object" task, improved cleaning possibilities and a slightly reduced height. Two design concepts and cardboard models were developed to work with all partners on ergonomics and robot arm reachability. A CAD file of HOBBIT's body and head has been developed in close collaboration with partners working with the electronic components.

A concept for a **behaviour framework based on the Mutual Care idea** has been developed and will be implemented in PT2. It encapsulates the underlying behaviour model for easy use by the execution modules. The behaviour will be based on a set of parameters that can be changed directly by the user or by adaptation to evolving needs.

HOBBIT provides **connections to AAL (Ambient Assisted Living)** solutions. The main achievement of this work was to find suitable sensors and actuators for the AAL System. Therefore, a list of possible devices, which are mostly wireless components, was obtained. For

PT1 we followed the user request and implement a call button. The call button, based on wireless components producing energy from pressing the button, is used to call the robot to a specified location. Call buttons can be freely placed within the apartment of the user. For PT2 an advanced AAL interface has been developed which allows the integration of further sensors and actuators in the user's home environment. General interfaces to other AAL frameworks like openHAB or universAAL were studied for future implementation.

A rich set of **HOBBIT visual competences** were realized and integrated to the PT1 platform and were successfully evaluated during laboratory and pilot tests. Their final and most significant evaluation was performed during the user trials conducted from PrM12 to PrM18. A direct outcome of these evaluation efforts was a new list of user needs and requirements that formed the basis for redesigning some of the existing visual competences and the definition of new ones to become available in the PT2 platform. More specifically, we adapted the initially developed 3D modelling, localisation and tracking of humans to support humans in a standing but also in a sitting position. The gestural interface was redesigned to support efficient observation of the upper body and hand/fingers of the humans. Two different levels of human-robot interaction have been identified, short (close up) interaction and normal-range interaction. Close-up interaction is realized through hand-based gestures, while normal-range interaction through whole body gestures. Moreover, the actual vocabulary for gestural human-robot interaction has been redesigned based on the feedback of the elderly users with respect to intuitiveness and convenience of physical execution.

The need for a pointing gesture was also validated during the trials and was implemented as a visual competence. Therefore, the standing or sitting user is able to extend her/his arm and point to an unknown object on the floor assisting the robot to detect it and pick it up.

A new application, the "fitness function" has also been conceived based on user input and aspires to serve as a vision-based physical trainer of a standing or sitting user. The system will prompt the user to follow physical exercises demonstrated in videos on the touch screen of the robot. Based on the 3D human detection and skeletal tracking that have already been implemented, HOBBIT-PT2 will be able to monitor the execution of such exercises as they are performed by the user and confirm their correct execution or identify mistakes and inaccuracies. Based on this evidence, HOBBIT will be able to either reward the user, or provide advice toward an improved execution.

Emergency detection has been identified as one of the top HOBBIT priorities. We have successfully tested a first approach of fall detection during the PT1 trials. A new methodology for detection of an already fallen user is under development in PT2 based on depth and thermal visual data.

Further ongoing work regards the development of a novel aspect of the gesture recognition interface. The new framework will not only permit the recognition of a set of predefined gestures but will make possible the dynamic extension of this basic set and its customization according to personalized needs and preferences.

Finally, the integration of the "Follow me" functionality is under development in the context of the new scenarios and commands that the PT2 platform will support.

Regarding **Navigation**, HOBBIT replaces the commonly used laser sensors with two RGB-D sensors. One sensor is mounted just above the floor and looks forward. It is used for **mapping and localisation**. Tests showed that the robot can navigate indoor environments such as homes given a minimum distance for the robot to pass. The map is built first and with a simple tool we annotate rooms. Next all places of interest to the user can be programmed by leading the robot to these places. Call buttons (AAL component) can be used at different locations to call the robot to a pre-defined Places are given names and are automatically associated to rooms. In this was we obtain a hierarchical room – place structure that is good for larger apartments and cognitively similar to how humans refer to places. Localisation has been tested and it turned out to be accurately enough to place the robot within a few centimetres of the desired place. The second RGB-D sensor is mounted on the head and can look down on front of the robot. It is used to **detect drivable floor and obstacles**. Navigation will then adapt its path as long as there is sufficient space. In case of a way blocked, the robot will notify the user and ask to remove the obstacle. Navigation plans paths between any stored places. Mapping and navigation have been tested with several settings and also introducing narrow passages. At present we test with PT1. The methods will be ported to PT2 early next year. The concept of two RGB-D sensors will remain also for PT2. With this sensor configuration it is possible to replace costly laser scanners while additionally scan over all height ranges relevant for the robot and it allows the robot to see on tables, which is necessary for object search.

Regarding **object detection**, HOBBIT will provide the **functionality to** first **learn objects** dear to the user and to then search for then objects. We provide a learning method based on texture and shape of the object which allows to model objects that can be put on the turntable in the robots hand. While dimensions are limited to be neither too small not too large, it is the first time such a functionality is put forward and made available to the user directly. Additionally, it will be the first time with HOBBIT that a robot will search for a learned object in the user's apartment. We will also provide an option to pre-store objects. The methods have been tested on a set of objects that have been named by users, such as key chain, wallet, mobile phone, glass case, handbag, cup, mug, bottle and similar objects.
To **search for the learned objects** we introduce an object detection pipeline that combines the strength of three different methods to detect objects. It uses a correspondence grouping and a refinement step to verify object locations and delivers accurate pose (position and orientation) of the detected object. It is further planned that object viewings will be stored and can additionally be used to guide the search for an object, e.g., by starting first at the location where it has been seen recently.

An important functionality of HOBBIT is to **grasp object from the floor** - a primary need **to prevent** potential **falls**. Hence, we improved the method for grasp point detection (Height Accumulated Features - HAF) and extended it to cope with certain situations where objects were placed on top of bigger objects (like boxes) and near to the objects boarder of these bigger objects. These improvements were published at ICRA 2013. Furthermore, the results demonstrate the capability of the approach to grasp objects in cluttered environments (e.g. in a pile of objects). To make this work on HOBBIT we obtain a calibration between the head camera and the arm and gripper based on markers and improved the trajectory planning. While tests are carried out with PT1, we already conducted many simulations with the new arm for PT2, which will have 6DOF, one DOF more than the PT1. With this new arm reachability will be highly improved.

The HOBBIT robot now exists in two samples of the first prototype, PT1. These robots have been used for the user trials and reported and shown in workshops and the media and created high interest. For example, Euronews sent HOBBIT at least in French and Spanish news. HOBBIT is mostly shown to pick-up an object for older persons as means of fall prevention.

Learning from PT1, we started to draft and design PT2. It will be slightly smaller and it will have more functionalities including full mapping of homes, search for objects in homes, entertainment functions and even a fitness application. The design is expected to be unveiled in spring 2014.
HOBBIT also investigates walk and rise functions. Concepts for walking assistance have been drafted in a one-handed and a two-handed solution. However, users prefer to see rise functions implemented. Hence we focus on the two main rise functions. A **rise-from-chair** functionality has been developed to be tested in PT2 lab trials. It is based on a concept where the user can get support from HOBBIT without compromising HOBBIT's stability by triggering the user to lean forward and support one knee while they are making a pushing down force instead of a pulling force. We have made prototypes and tested them with two old users. Similarly, a **rise-from-floor** concept has been developed, which is based on the idea that HOBBIT could bring an object which enables older adults to safely get up from the floor on their own. We developed a conceptual prototype for this object together with physiotherapists and currently test it with potential end users.

The project kept its homepage alive. **Project website address:** http://hobbit-project.eu/
Details are reported in D9.1, which is open for download. The Web-page complies now with the World Wide Web Consortium's Web Content Accessibility Guidelines, which makes it accessible according to W3C-WAI Web Content Accessibility Guidelines (WCAG 2.0).

The Web-page hosts now more material for download, for example a new project folder, a short presentation, and many of the publications have been made available for direct download. The project is proud to receive excellent coverage in the public. News items continue to be produced and the web-page is kept up to date.

The **final results** of the HOBBIT project address several socio-economic and wider societal impacts. Acceptance for robots in the homes of elderly will increase through the mutual care concept. This will increase, or speed up the increase, of service robots caring for elderly at home. Both the HOBBIT robot, as well as other robots will benefit from the proven increased acceptance of the mutual care concept (PT1 trials). As this concept includes both hardware and software components, at a minimum the software components can be incorporated in any future robot. The increase in acceptance will increase the number of robots active in caring for the elderly, which is still a major societal and socio-economic challenge.

The results of PT1 user trials indicate that the acceptance for robots before and after a trial with the HOBBIT robot significantly increases. It confirmed that the acceptance of robotic helpers can be significantly increased though mutual care.

The cost (time) of informal care is currently burdened in large by females family members, giving informal care to relatives. HOBBIT will decrease the need for time spent by women for care, thereby increasing their available time to peruse either a career or to be used for recreation, thereby increasing the Qality of Life (QoL) not only of the elderly, but also of their informal caregivers.

Furthermore, the focus of HOBBIT on fall prevention can significantly increase the QoL for elderly people living independently. The increased time they can stay in their own home, along with the pains associated with a fracture at a higher age are significant improvements to the QoL of elderly. This has both a socio economic dimension, as elderly patients who suffer from a fracture have high treatment costs, as well as a **societal implication**, as it enables an elderly who are not as mobile to continue to interact with society, through a device tailored to their specific needs.

The final result will be a robot that improves the quality of live and prolong independent living of senior citizens through the fall prevention, fall detection and auxiliary functions of the mutual care robot. The expected **socio-economic impact** is to present a prototype mutual care robot (HOBBIT) as unique selling point for European industry including the conceptual approach of Mutual Care to increase user acceptance through human-machine bonding.