Chapter 2

User Experience Results of Setting Free a Service Robot for Older Adults at Home

Markus Vincze, Markus Bajones, Markus Suchi,
Daniel Wolf, Lara Lammer, Astrid Weiss and
David Fischinger

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.70453

Abstract

The chapter presents the analysis of user trials where, for the first time, a service robot was set free in the home of users. Different to previous studies there was no pre-specified schedule of tasks to execute. The goal was to show that useful functionalities for users can also be achieved with the low-cost components of the Hobbit robot. With the one-arm mobile service robot Hobbit we provided users with a service robot running basic robot functionalities such as navigation, grasping objects from the floor, emergency handling, entertainment, fitness and communication functions. Users could freely select what to do over the three-week trials in homes in three European countries. Users have been questioned on what functionality would help them to stay longer at home and live independently. Results provide better insights of what users want than in pre-set scenarios, where many of the factors we encountered do not show up. Good examples are the need to have robots navigate autonomously at home, grasping objects from the floor is a highly valued function, and the robot needs to adapt locations depending on the daily liking of the users who move much more freely at home than in pre-set scenarios.

Keywords: service robots, personal robots, autonomous navigation, grasping, user experience at home, object recognition

1. Introduction

Robots have long been a dream of humans as helpers. We started from the vision of a robot helper at home. While there may be a large literature and demand for robot to help all people in particular with household chores, too many of the chores are not yet possible to technically realise. Hence, we rather considered present robot technical capabilities and started to envision the role of a home robot enabling older people to feel safe and stay longer in their homes. The result of two iterations of user-centred design is the Hobbit robot. **Figure 1** shows the robot and lists its main components, which will be introduced in more detail later.

The rationale behind this selection of feeling safe at home is that when an older adult falls it is necessary to transfer to a care facility. Since this is the primary cause for these transitions, any measure to increase the perceived safety at home will aid to improve the situation for the users. Consequently, we introduce a mobile robotic solution that sets out to discover falls. It does so in a proactive way to avoid falls in the first place. The concept has been developed together with professional care personnel. The result is the robot Hobbit. It provides a set of

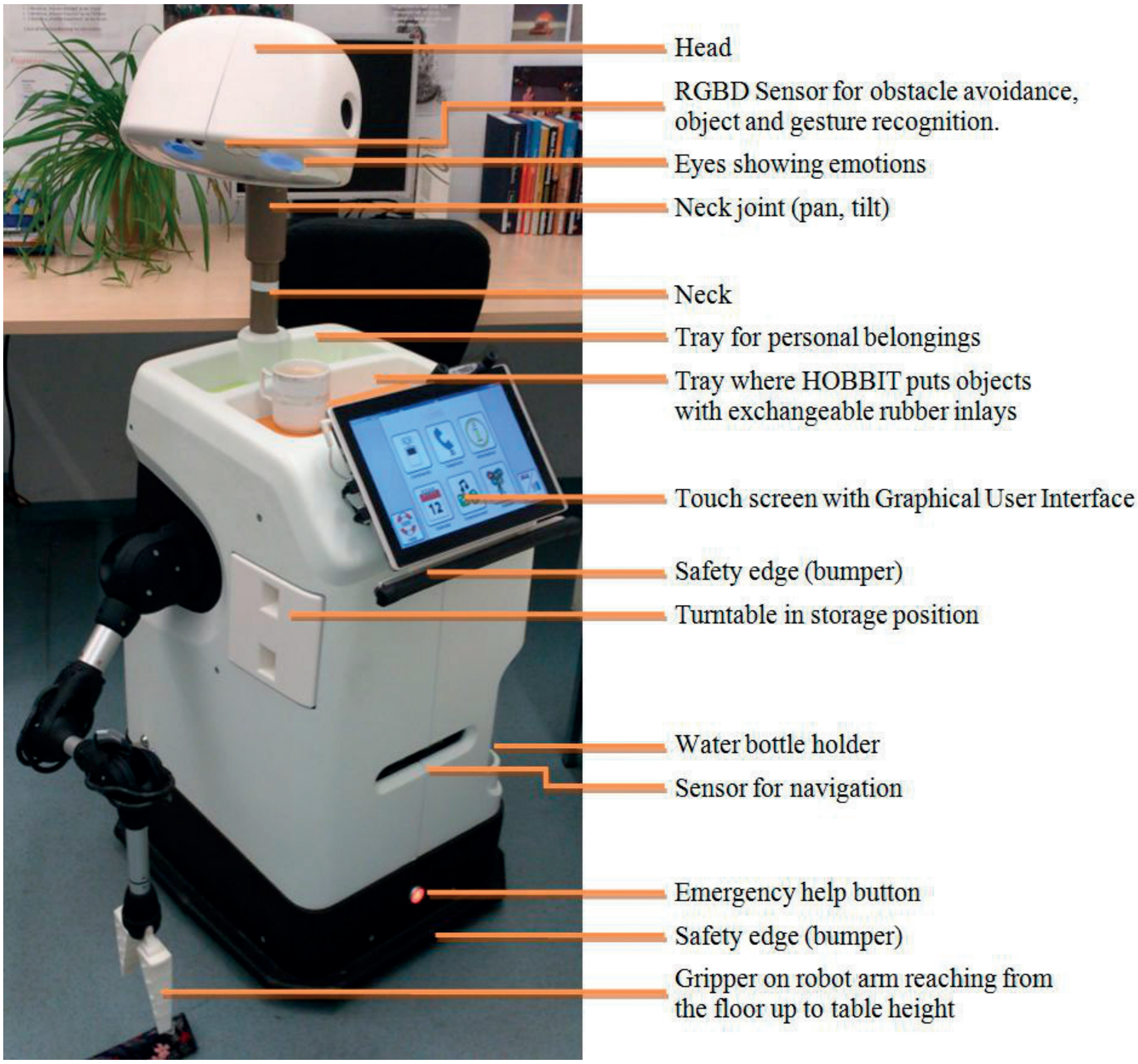

Figure 1. The service robot Hobbit designed to help older adults stay longer independent at home. Its primary functionality is coping with emergency situations, grasping objects from the floor or transporting objects to avoid falls and is a good collection of entertainment and physical and cognitive fitness functions.

functionalities to the older adults. It uses multimodal interface based on speech, gestures and touch-screen for realising easy-to-use human-robot interaction (HRI).

Today, there are several service robot solutions targeting the application of an extended video phone. However, these do not include an arm to actively interact with objects in the user home. The highest developed robot with similar capability as Hobbit is Care-O-bot. It has been tested in many trials in care facilities for studying user interaction, for example, for bringing water or other assistive operations in care facilities [1]. However, this robot is too large to operate at homes; it would hardly fit through doors. Many of the remaining mobile service robots, for example, Giraff, are not able to autonomously navigate and need to be operated remotely.

The main novelty was to bring a service robot into user homes that can do more than a video phone on wheels that is operated by a remote user including the navigational capacity. The designed Hobbit robot provided to the user the following functions:

- Maintaining the user's self-efficacy is addressed with exercising cognitive and physical skills (social connectedness and fitness functions).
- Increasing the perceived user safety is addressed by managing a safe home including functions such as emergency detection, grasping from the floor, transporting objects, patrolling to check for the user and calling the robot.
- Positive affect towards the robot is addressed using entertainment functions. This also increases the user's well-being.

A unique setting of the Hobbit study was that users were free to select any of the functions at any time.

In this contribution we report the findings of the user experiences with the Hobbit robot. The trials involved 18 users in 3 different countries spanning from the north to the south of Europe: Sweden, Austria and Greece. Since the users wdid not have any given schedules or scripts, they were free to use the robot as they wanted. The idea was to set the robot free to better find out what the users would really want from the robot rather than presenting the users with a fixed script or setting as in previous studies.

The chapter proceeds as follows. After a review of related service robots for elder care, we present results of a study on what the robot should be able to do in a safe home scenario (Section 3). Section 4 presents the robot and its components and Section 5 presents the results of the user study.

2. Related work

Service robots for older adults are typically aligned according to their capability to address activities of daily living (ADL) or instrumental ADL (IADL). However, typical functions of ADL/IADL are dressing, food preparation, eating, cleaning and rehabilitation or direct physical exercise activities. All these functions are very difficult to realise, and there are only a few robots in research settings progressing towards one of these functions. Hence, we took another approach to realise a useful robot. Coming from the fundamental need of feeling safe at home, we introduced a series of functions to maintain safety at home and augment this with functions to entertain and motivate the user. The intention is to create a positive effect with these socialising functions.

Studies can be compared on where user trials have been conducted. Indeed, very few studies go beyond tests in professional care facilities, and even fewer study longer durations, for example [2] and a recent survey in [3]. In the following we highlight recent developments. Today, many service robot projects further advance one specific functionality. For example, in GrowMeUp (http://www.growmeup.eu/), the user's habits, preferences and routines are studied using multiple sensors on the robot and the environment. The robot is a reduced PAL platform without arms from Pal Robotics (http://pal-robotics.com). As we have seen in our user experiences, relying on an external sensor network may be feasible in specially designed homes but is not welcome by users at home and requires substantial installations and the related costs.

The EU project EnrichMe (http://www.enrichme.eu) also studies the use of touch-screen and augmented user interface as a follow-up of the CompanionAble Project with Robosoft and the Kampai robot. Ambient-assisted living (AAL) functions are used by introducing radio-frequency identification (RFID) chips into objects. Project Mario (http://www.mario-project.eu/) addresses isolation, loneliness and dementia of older adults through multi-faceted interventions delivered by service robots including the use of AAL installations. The project partners use a near state of the art platform based on the Pal Robotics robot that is 'flexible, modular friendly, low cost and close to market ready in order to realise field contributions in the immediate future'.

An aspect that has to be kept in mind is that the generation of adult 70+ users included in the developments here differs from future older users in regard to experience with and acceptance of technology. Currently, literature discusses the so-called digital divide between people over 70 and younger users. This digital divide is shrinking (cf. [4]). This means it can be assumed that future older users will face less difficulty in using, for instance, web browsers and other computer tools than the older generation of today. In fact, Hanson argues that older adults form the fastest-growing group of web users. In other words, future users may be more critical with the interface but less afraid of using new technology.

On the other side, age-related functional limitations affecting interaction with computers and other interactive devices will very likely stay the same for future generations of older users. These include cognitive changes with regard to short-term memory, concentration and also solving of new types of problems, as well as common perceptual impairments (sight and hearing), and finally reduced motor skills. Such perceptual and motor impairments are taken into account for the design of a user-friendly multimodal user interface (MMUI) that is to be evaluated in the user trials (based on experience from other projects with older users, such as KSERA).

The contribution of the work presented here is a robot that acts fully autonomously in the home of the user - the Hobbit robot. As pointed out in this review, up to today robots have rather been remotely operated, or a small number of tasks in the user home have been studied in the user tests. Examples are projects such as Giraff++, SRS and Robot-Era. Some of the coordinators of these projects pointed out that these robots urgently need the capability of autonomously navigating in the user homes. And exactly, this is the capability developed within the Hobbit project, and it will be of good future use when moving towards longer-term tests at home.

3. Requirements of a home robot for increasing the perceived safety of older adults

Studies in service robotics repeatedly reported the requirements humans have to robots. The top are the well-known four Cs for cleaning toilet, bath, kitchen and windows. This need is confirmed even in our user trials. An older lady saw the robot and immediately responded with 'I do not need this robot, it cannot clean windows'. This clearly indicates that this is a rather large gap between what users in general, not only older adults, would want from a robot and what robots are actually able to do today.

Conscious of this gap and of what robots can actually perform today and what users would want, one of the motivations for running the Hobbit robot in the user homes was to get a better understanding of what services the robot could actually provide.

Consequently, we started from functions and services that a robot *could* provide to users. In a first study to investigate what older adults (primary users (PUs)) would need at home, we conducted a questionnaire with questions regarding the functionality, safety and operation of a home robot. The user consisted of 113 persons with an average age of 76.2 years. Overall, 69 (61.1%) of this group were female and 43 (38.1%) male. Forty-six (40.7%) of the primary users were single-living, whereas the remainder stated to live with 1 or more persons in the household; 18 people did not answer the question. The majority of interviewees lived in a flat (59.3%), 24.8% in a house, 14.2% in a nursing home. Two persons did not answer the question. Most PUs (62.8%) did not receive any home help service, healthcare service or support from relatives. Only six (5.3%) interviewees were permanently living with relatives or a care service. Asked about the frequency of using a computer, 49 persons (43.4%) stated not to use computers at all and 38 (33.6%) to use computers every day. This balanced amount of 'computer literacy' makes for an even sample, since many potential purchasers of Hobbits on the market cannot be expected to have experience with handling computers.

Tables 1–3 summarise the most important results of the frequency analyses for the questions within the group of primary users (n = 113). Sample size varies for each item, due to varying numbers of answers. Not every participant answered every question. **Tables 1–3** depict the above average percentages of 'agree' answers to the questions. Most users wanted their robot to be able to search and find things, grasp objects from the floor and from a shelf and also bring objects to them (**Table 1**). Other important functions were reminding users of appointments or phone calls and their medication.

Question	Valid sample	Percentage
Search and find	107	86.9
Grasp from the floor	109	86.2
Grasp from the shelf	105	80.0
Fetch and bring	106	79.2
Reminder (appointments or phone calls)	106	78.3
Reminder (medication)	107	77.6
Carry objects	104	68.3
Follow	104	66.3

Table 1. Most wanted functionalities of the service robot.

The majority agreed that they felt safe, if the robot could call for help (see **Table 2**). About 61.8% of the valid sample agreed that they wanted their robot to be active at night; this percentage becomes even stronger when those who chose 'I rather agree' are also added. The accumulated frequency then reaches 81.8%. Only 8 of 112 PUs (7.1%) stated that they felt frightened by the idea of having a robot at home.

The idea of having the robot taking care of its own battery level is highly popular (96.4% of 112 answers). On the other hand, users like to stay in control. This is reflected in the high amount of 'agree' answers to the statement that the robot can only do what it is told by the user. This topic has to be considered carefully when designing autonomously triggered activities of the Hobbit system (e.g. reminders). Operation of the robot should be preferably speech based. Remote control is in the second place, followed by gestures and touch-screen (see **Table 3**).

3.1. The functions provided by the Hobbit robot

The results presented herein mark a significant step forwards in evaluating robotic systems under real-life conditions [5]. For reasons of completeness, we shortly set the above presented functions in relation to state-of-the-art robots (see also [6]).

The selections of functions that have been implemented on the robot have been extracted from multiple interactions with users, secondary users or relatives and professional caregivers. We conducted first home trials with an autonomous robot with the aim to find out what users want.

Question	Valid sample	Percentage
Safe because of call for help	112	85.7
Active at night	110	61.8
Frightening	112	7.10

Table 2. Most wanted safety aspects of the service robot.

Question	Valid sample	Percentage
Self-charging system	112	96.4
Interaction through speech	102	88.2
Operation by speech	96	85.4
Do what I ask for	113	72.6
Operation by remote control	97	68.0
Move everywhere	108	65.7

Table 3. Most wanted modes of operating the service robot.

Here, a lot more work is needed, and recently started projects will expand our understanding. Part of this work was that we conducted two iterations of user studies and collected user requirements [7]. These requirements give a clear picture of what older adults would want at present from a robot helper at home. Conclusions are drawn from workshops with older adults that created a longer list of requirements that have then been ranked in studies and questionnaires and correlated with technical feasibility given the present state of the art in service robotics. We used first user trials and lessons learned to verify the ranked requirements [8].

Before reviewing the robot system concept (Section 4), we summarise the user requirements and relate them to other studies or care robots. The clear requirements formulated within the Hobbit project still hold. The main services that a home robot should provide to aid older adults target the following needs. Note that the items listed below are the convergence of functionalities that can actually be provided by the robot and the results of the questionnaires given in **Tables (1–3)**:

- Maintain the user's efficacy level: this includes functions for keeping an active and fulfilled live and includes:
  - Social connectedness includes telephone and Internet access to alternative ways of communication such as a video call or to access weather, news and other information.
  - Physical and cognitive fitness includes physical exercises that have been considered on top of the initial description of work. This includes games and playing music or video or radio, a function that has been surprisingly welcome by users to play the favourite radio station.
- Increase the perceived safety of the user:
  - A main aspect is already the physical presence of the robot and its care functions such as seeking the user and user interaction during the patrolling function.
  - Multimodal interaction capabilities and several ways to trigger an emergency call.
  - Pick-up of known and unknown objects from the floor which turned out to be an essential aspect. The normal scepticism towards the robot went away after seeing the robot picking up an object from the floor. A clean-up function further extends this capability.

- The robot provided an additional safety check with the user, making her/him aware of hazards at home while proposing solutions or options to assist.
- Calling the robot for help: the use of call buttons is an effective means to call the robot for any task at any time.

- Functions for the user's well-being: here, we summarise services that are nice to have and will actually assist to accept the platform and keep it in use. In the Hobbit idea, we had drawn out many of these functions as elements to make the user feel good and possibly even create a bonding to the robot such that it is trusted and used and the previous two aspects are reached to an even better degree. Examples of these functions are:
  - A first personalisation of the robot is executed in the initialisation phase. The users set initial parameters, which could be changed later. Additionally, the robot and basic guidelines for operating it are introduced.
  - Learning new objects and findings these objects are welcome features for the users and regarded as a great commodity.
  - An important functionality that extends the functionalities provided in Hobbit is the pick-up from high locations. Grasping objects from places high up that cannot easily be reached will be investigated in EU project RAMCIP, though robot costs are expected to be considerable higher. In Hobbit we regard this functionality as a future module and a possible extension of the basic robot platform.
  - Entertainment ranges from games over music to surprising the user. All these functions aim at increasing the user acceptance.
  - Reward functionality is a means to enhance the user binding with the hypothesis to improve the acceptance by the user.

In summary, the Hobbit robot provides a rich repertoire of functions, where several are novel and have been tested with users or at home for the first time.

4. The components of the Hobbit robot

The main components of the robot have already been depicted in **Figure 1**. The robot platform used for the home trials has differential drive kinematics developed by MetraLabs: a floor-parallel depth camera for purposes of navigation, a head mounted 120 cm above the ground to the level of the height of a sitting person, a touch-screen mounted at an angle in front of the torso or the robot and on the right side of the robot a manipulator to pick up objects. The head contains two screens to present the robot's eyes and an RGBD camera (ASUS Xtion). This configuration is an improvement of the previous Hobbit version and implements the lessons learned in a series of previous user trials (see also for details [9]). The main dimensions have been reduced to follow user requests. The height of the Hobbit robot is now 125 cm, and it has a width of maximum 56 cm at the point where the shoulder of the arm sticks slightly out beyond the robot. Other features will be discussed in Section 5 when discussing the hull or individual features of the upper body and the head.

A key element of the development of the Hobbit robot set out to reduce the costs of the hardware costs to a minimum. For example, laser sensors are rather expensive and only operate in one plane. Replacing them with RGBD camera has the advantage that their cost will be lower and they provide full 3D perception. Hence, we can test the feasibility to cope with all the functionality needed at home and with lower price to reach closer to the expected costs of presenting a robot for home robotics. The hardware components sum up to 16,000 Euro. **Figure 1** presented the Hobbit robot with its main components. Navigation is autonomous and uses virtual laser scans from RGBD images. The robot operates using a multimodal user interface (MMUI) that comprises a graphical user interface (GUI) with touch-screen, automatic speech recognition (ASR), text to speech (TTS) and gesture recognition interface (GRI). The robot has functions for edutainment (music, radio, audiobooks, pre-installed web radio and services, games and cognitive fitness functions), reminders, video phone service, control of a manipulator, access to an ambient-assisted living (AAL) environment (e.g. call buttons) and emergency call features. The robot's functionalities included automatic emergency detection (e.g. patrolling and detecting persons lying on the floor), handling emergencies (communication with relatives) and supportive fall prevention measures (transporting small items, picking up objects from the floor, searching for objects the robot had been taught by the user).

5. Results of setting free a service robot for older adults at home

In the following we structure the results into the aspects regarding the robot usage (usability, acceptance and affordability) and issues related to the robot hardware, software and development. Before presenting the results, we summarise the design and methods used to evaluate the user trials.

5.1. Design and methods of the user trials

The user trials have been conducted in three countries, and users tested the robot for 3 weeks each. The trials took place in Austria with seven end-users, in Greece with four end-users and in Sweden again with seven end-users. In total, the trials included 18 primary users (PUs) and 16 secondary users (SU). The trials were carried out in the user homes with the robot interacting autonomously for 3 weeks with the user. All trials took place in private homes of single-living senior adults. Each trial with one user lasted 3 weeks. In total, the robot was deployed for 372 days. Assessment by means of qualitative interviews and questionnaires took place at four stages of each trial: pre-trial, midterm, end of trial and posttrial (i.e. 1 week after the trial had ended). Results of the qualitative interviews as well as perceived safety measured by the falls efficacy scale (FES) [10] are reported. Eighteen elderly users participated in this study, and 16 (14 female) were included for statistical analysis (two participants had to be excluded because of missing data). The mean age was 80 years, ranging from 75 to 89 years. Qualitative data were organised using NVivo (QSR International). Quantitative data were analysed using SPSS by means of descriptive statistics and non-parametric methods (Friedman ranking test).

We used a multi-method approach for testing the most important evaluation criteria: (1) usability; (2) acceptance, which includes the mutual care (MuC) concept [11]) and (3) affordability.

This testing followed an intricate evaluation procedure with regular updates using the inputs of the reviewers of the project and the first experiences of the pilot user tests [9]. The method mix used contained interviews; questionnaires; cultural probing with the older adults before, during and after the trials; and the continuous logging of all interaction data in the Hobbit robot (see **Figure 2**). Qualitative, quantitative, cultural probing and logging data were preprocessed and analysed according to state-of-the-art scientific rules and procedures. Detailed results of the field trials will be reported.

5.2. Results regarding overall robot usage

As outlined above, results were gained from questionnaires; interviews; cultural probing with the participants before, during and after the trials; and continuous logging of all interaction data in the Hobbit robot. Qualitative, quantitative, cultural probing and logging data were preprocessed and analysed according to state-of-the-art scientific rules and procedures. Detailed results of the field trials will be reported. The most important results of the user trials related to the three main quality criteria were:

- Usability: users agreed that Hobbit is easy to use and intuitive to handle. The option to use different input modalities was perceived as very helpful for PUs. There was, however,

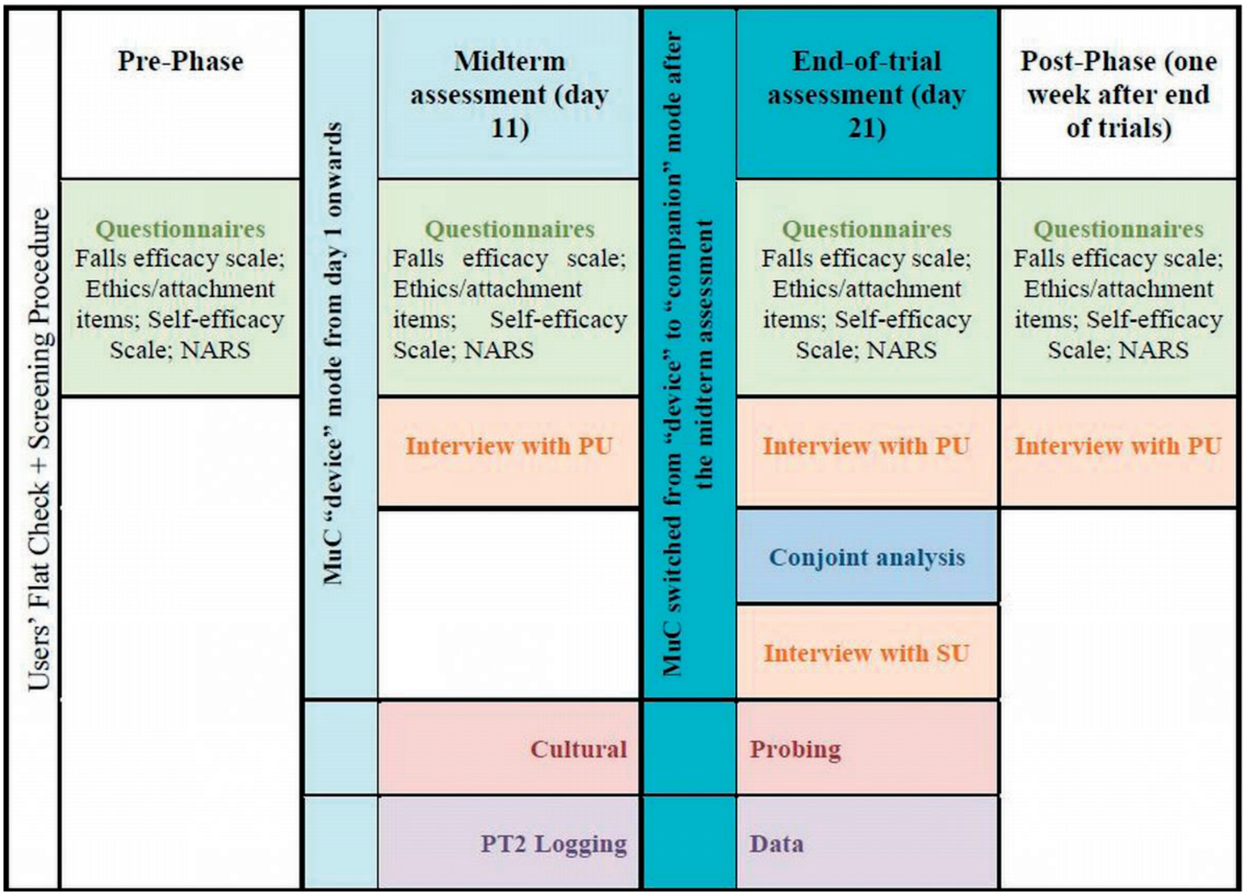

Figure 2. Overview of trial procedure and evaluation materials.

some lack of functionality, since not all functions worked all the time. This was acceptable for a prototype but obviously needs to be improved.

- Acceptance was ambivalent among users. In general the attitude towards the robot was positive and did not change. The emotional attachment weakened over the duration of the trials, mainly due to the technical problems. This also indicates that some of the expectations of the users could not be fulfilled. A more important finding is that the reciprocity was not perceived by the primary users. This indicates that the mutual care approach needs some refinement to become effective.
- Affordability: The results of the user trials indicate that the Hobbit robot is with its current price of 16,000 Euro—not yet affordable for the target users. While this is more than a magnitude cheaper than other similar robots, it is too expensive. On the other hand, a robot arm would be cheaper but is not wanted. Only a complete Hobbit robot with a pan/tilt head, a manipulators and functions for pick-up and for learning objects will all be valuable for PUs.

Using the qualitative data of the user trails, we can obtain insights on how the users like the different functions Hobbit provides. The users mostly appreciated the function to pick up objects, where picking up from the floor has rates with the highest value. Other highly welcome functions are detecting potential emergencies (adding to the feeling of perceived safety), the transport of objects, the cognitive and physical fitness functions and to be present to the user reminders. Although the pick-up function sometimes had failures and only worked without any difficulties for 18% in total of 372 days, users still saw the high potential. If this function would be available, users would want it. All in all, speed of operation of the robot system is not as good as it should be. Neither voice commands nor gestures operated to the expectations of the users. Consequently, the touch-screen has been used more often. To conclude, quantitative data shows that the perceived safety for the users, which is obtained using the Falls efficacy scale (FES) measure, did not increase along the user tests ($p = 0.265$).

Finally, the mutual care (MuC) concept, which has been proposed to foster the acceptance and improve the use of robot, has been detected to have rather little consequence. A cause for this unexpected result may be with high probability that the technical functioning of the robot is not yet high enough. Hence, there is considerable work ahead. While the trials indicate a first proof of concept, there needs to be more added reliability of all the robot operations. The good finding is that navigation is autonomous and with a service rate of over 98% was rated as sufficient by users. Hence, we provided a very good start for gaining acceptance by the users. Let us now have a closer look at the next step of technical improvements.

5.3. Results regarding technical improvements towards future home robots

A general conclusion is that robots such as Care-O-bot or Giraff are too big to be operated at homes. Users expect to be sitting when interacting with the robot. Consequently, robot height should be about a sitting height of a person. Ideal is about 120 cm. So, Hobbit is still 5 cm too high but comes close to the ideal. Interestingly, the only robot so far at this height is Pepper of SoftBank Robotics.

Home robots may first be used in the homes of older adults. In these envinronments many things have been accumulated over the years, hence space is sparse. Ideally, the robot footprint does not exceed a diameter of 40 cm, which is technically difficult to reach including an arm. The shape of the robot may be rectangular; however, to simplify the robot's navigation capabilities, our findings propose a cylindrical shape. This will make rotating behaviours simpler and allows an easier navigation through doors, which have been found to be as narrow as 60 cm, in particular in Sweden. Finally, a recommendation is to build the robot manipulator within the hull of the robot. It then will not collide with furniture or doors and walls when the robot is rotating or moving in the apartment.

A difficulty in many homes is not even floors and thresholds. Thresholds as high as 25 mm were encountered many times. We resolved the issue temporarily with ramps. However, it would be better to devise an efficient solution based on wheels to surpass small thresholds. Additions to the apartment are not always welcome by the users. Some examples of coping with thresholds are shown in **Figure 3**.

The battery duration of the Hobbit turned out to be sufficient. It lasted for about 8 hours of continuous robot uptime. A user will not use the robot this long. Users got tired after about 2 hours and sent the robot to go to the recharge station. Furthermore, for reasons of safety, the robot must always have a battery level of at least 30% to make sure that it can patrol the user home, locate the user and if necessary has enough power to initiate and operate through a full emergency scenario. The present implementation based on voltage was not ideal to reliably report remaining battery status. The battery status was not transparent for the user. Ideally, it should estimate the remaining run time.

Another more practical issue is the docking station. It needs to be small, since there is not much space in the homes of older adults, as stated above. It may contain markers for improving robust docking behaviour, but we simply used a trapezoid shape, which turned out to be sufficient. **Figure 4** depicts the docking station.

Another practical issue is a way to stop the robot at any time. While we use a hardware on/off button, a practice showed that there should also be a 'cancel' hardware button or switch that would allow the user to cancel immediately whatever activity the robot is doing at any given moment. The advantage of this button is also that this could be done remotely so that the user does not have to approach the robot. This will be a simple add-on and put the user in charge of the robot at any time.

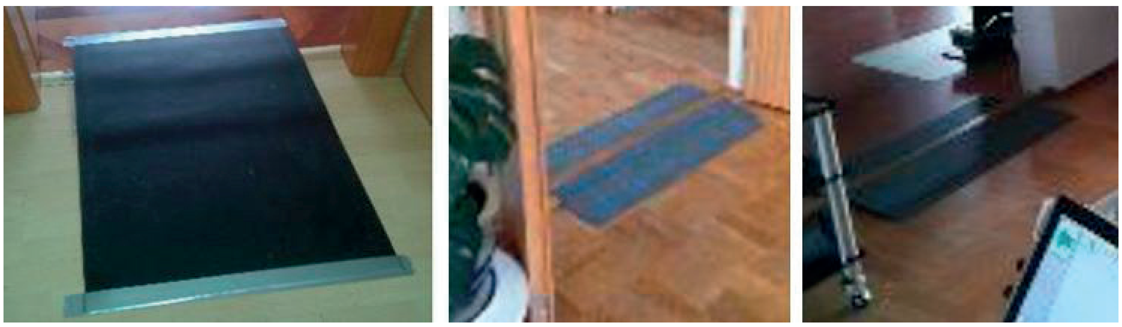

Figure 3. Several examples of mats and ramps to make the floor flat enough for a wheeled robot.

Figure 4. Docking station (black) and the robot wrapped in plastic for temperature tests.

5.4. Robot safety edges and bumpers

Hobbit was equipped with safety edges (see **Figure 5**) at the base plate and the tablet's base plate. They are electrically interconnected with the main electronics forcing the Hobbit robot to stop when it is colliding with obstacles or humans. In this case the electro-conductive inner sides of the safety edges are pressed together, and the resulting signal leads the main electronic to stop the drive motors.

The main bumper (**Figure 5**(left)) is at the floor and also assures that the user cannot get under the robot, e.g. with the foot. However, in a few cases, shelves would protrude just above the bumper. To address this it would be helpful to design a second bumper at 20 cm height so kitchen cupboards with cabinet plinths are not in a risk to be hit. For a commercial product, a low-cost solution for the bumper needs to be determined.

At present the robot has no sensors pointing backwards; only the bumper goes all way around. However, an infrared or sonar sensor such as additional sensor and further forward-looking sensor could be added. With the additional sensor at a height of 20 cm and a better localisation and mapping method, this issue could also be handled.

At night users would want Hobbit to be silent and dark. As a consequence, Hobbit should not have any lights on when it is not active or sleeping in the charging station. The LEDs at the

Figure 5. Safety bumper all around the base plate (left, only the front view of the robot is shown) and (right) tablet base bumper (the black rubber band below the tablet).

switches of Hobbit, the touch-screen on the charging station and even the eyes of Hobbit are too bright at night when the user wants to sleep. Similarly, when the user presses the Away/Sleep button, the robot should not radiate light.

5.5. Considerations for the design of the robot hull

The outside hull to cover all the body is essential for the presentation of the robot. It is important to have a good first impression as well as high functionality. The design carried out in Hobbit turned out to be very good and provided all the features necessary, for example, the drinking bottle mounted low on the robot for emergency cases.

As a start of the investigations into the Hobbit robot, several workshops had been conducted with older adults for indicating the requirements from the side of the users to the robot hull. **Figure 6** shows some of the example robot models created. Often modelled characteristics are soft but washable and hygienic materials, a slim body and two arms. Due to practical reasons and cost issues, only one arm has been realised. For all the functionality integrated in the top part of the hull and head, see the next section.

An issue regarding a safe robot motion is the mounting of the robot arm on the platform. Ideally, the entire arm should be within the limit of the footprint of the robot base platform. This is a challenge for the technical components: mobile arms of small size and reasonable payload do not yet exist. It also needs to be taken into account that during arm motion planning the arm motion will come out of the base footprint and hull. But it needs to be considered for avoiding self-collisions and collisions with the environment. Moving the arm and specifically the shoulder in a few centimetres is actually possible and is feasible in a final robot system concept.

Figure 6. Three of the proposals for the robot design from workshop participants using simple materials to build up a robot model. Note the common characteristics of soft materials, a slim body and two arms (the model of the left robot does not have arms but the description of the user).

http://dx.doi.org/10.5772/intechopen.70453

The design itself has been very good. A further functional improvement regards the practicability to mount and unmount the hull in cases of changes. This is of particular interest for earlier phases where this needs to be done more often but also for a product to allow good maintainability. For Hobbit we rather had the design and then considered how to best split up the hull for manufacturing as well as practical issues. In the next version, this aspect needs to be included into the design considerations already at design time.

One more issue of practical use, in particular in the phase of testing the robot and when introducing the robot to first home and user trials: data of the platform should be easy to access, for example, via a service socket. This is relatively easy to achieve by adding the necessary sockets, for example, USB to copy data rapidly or attach a keyboard, to add a network if there is a WLAN error or to connect a display to the system if the XPC does not start, or it is needed to change settings in the BIOS. This socket could be included into the design considerations such that it can be easily accessed without removing the hull. This will considerably simplify and speed up the development of the platform behaviour and performance.

Furthermore, the hull should be included in the heating concept, for example, to use materials that provide a better cooling or the use of ventilation slots that were not foreseen in Hobbit because of the risk of liquids by transporting water. In particular during the summer trials, the robot produced too much heat, and this was felt to be negative by the users.

5.6. Multiple functionalities for the active robot head

As the last section of future improvements, we investigate more detail how the active head of the Hobbit robot worked and what could be improved. The active head in itself actually

Figure 7. The upper body and the head of Hobbit. Also, depicted are the main components and functionalities.

turned out to be very useful. Note that users had indicated that there should be a head to make clear where to talk to. A main function the head and upper torso of the robot serve is to give the user a feeling of active presence of Hobbit. **Figure 7** gives more details about the upper body and the head. The key function of the active head is to enlarge the field of view of the otherwise limited RGBD sensor. With the head it now covers different functions including the detection of obstacles and humans, the recognition of gestures, the recognition of objects and the detection and manipulation of objects for pick-up from the floor. Blue Danube Robotics (www.bluedanuberobotics.at) designed and produced the active head.

Besides increasing the field of view, the head serves several other important functions. We list the most important ones (see also [6]):

• Attending to the user: an active head naturally presents the direction into which the robot is facing. The older adults in the user trials intuitively understood where the robot is looking. This renders the head motion very efficient: users immediately understood if the robot was busy with navigation when looking straight down or grasping/searching an object when looking around. When approaching the user, the robot would raise the head, and using human torso and face detection focuses the user. No additional means such as lights of verbal communication is necessary.

• Faster search operations: the active head does not need further robot motion to look all around. Moving the entire platform is much more expensive and all measures than simply moving the head. Also, with the up and down motion, near and far views can be sampled. There is the drawback that reliable operation needs a calibration of the pan/tilt motion. However, in the near future, we will present an automatic and continuous calibration function simply from moving the head.

• Detecting obstacles for reliable and safe navigation: the robot looks straight down when navigating. This allowed us to cover in more detail the ground in front of the robot. This is of particular interest when approaching a user, since hitting a foot is definitely not allowed with older adult users. It also covers the part of the blind area in front of the robot from the bottom RGBD camera for detecting walls and localisation. The touch-screen is the limit at present. But one might think of a detachable touch-screen or tablet, which further increases the operational range.

The present field of view (FOV) of typical RGBD sensors is about 58° horizontally and 43° vertically. A FOV with this limitation is presented by more or less all RGBD cameras including the Kinect. Sensors with other measurement principles such as time of flight (TOF), for example, the KinectOne, have about the same limitation. It may be interesting for sensor developers to think about this or to provide a direct integration with an active pan/tilt unit as proposed here.

Nevertheless, the present active head serves the purpose of attending to many different tasks such as viewing the floor in search of objects for possible pick-up, detecting obstacles during navigation, checking tables for objects that the user can ask for, the detection of persons, the recognition of gestures or user activities and the search for the user to increase her perceived feeling of safety. Particularly, in the last task, finding the user, a large FOV is needed. While the human visual FOV covers about 180°, the present head set-up needs three viewing directions to cover the same range. Still, with present camera resolution and the added advantages of an active head as listed above, we see this as the best set-up for a future home robot.

The functionality of an active gaze direction to show the user where the robot looks helps to create a bonding with the user as indicated by the trials. More work in this direction is ongoing, for example, [1, 12]. What is still missing are robots that robustly and smoothly focus onto the user in their natural environment at home. Another interesting point is that there is often a fixed approach to the user. However, at home, the exact location of chairs changes, and hence the location of the sitting user changes. This renders necessarily an adaptive approach to the older adult. In Ref. [13] a laser distance measure to the legs of a single user was used [13]. However, a more flexible and accurate method including the recognition of the user is asked for at-home robotics.

Let us give a few more insights to improve the head and robot operation. At present the faces are partially black and white. A completely dark face better hides the dark holes from the camera, whoever may not look appealing. Hiding the camera behind glasses disrupts camera accuracy and calibration. At present there is not perfect solution yet.

Another useful option is remote accessibility using a secure Internet link. It provides developers to keep track of the robot and, if any problems are encountered, to rapidly check without the need to physically reach the robot test site. Similarly, the hull should be easily detachable. If problems with the robot hardware need to be resolved, this will prove very useful.

An addition that may be necessary, depending on the environment, is ultrasonic sensors (US). In the cases we encountered, this was not necessary, but transparent surface is not visible to optical cameras such as the RGBD sensors and needs a complementary sensor modality such as US. Similarly, at present we did not have any sensors on the robot's backside. This was resolved by not driving backwards except out of the docking station, where it was known that there is space and the user was verbally notified that this would happen. An option is to increase the range of the active head to also look backwards. Another option is to add more US.

Finally, let us conclude with an important finding regarding the robot's safety. From the experiences in Hobbit and also other robot projects at home and in office settings, there are many cases where stairs lead downwards. While looking down at the floor is an option, this is a safety critical aspect, and, hence, it should have at least two if not three complementary measures to assure that the robot is driving forwards on safe ground. Floor detectors that use infrared sensors and blocking areas in the navigation software are too easy to realise options to considerably enhance the robot's operational safety. All needs to be integrated into the navigation system, but it will prove useful. As a manufacturer of a mobile robot clearly said, it will be able to fall down but only once.

6. Conclusion

This chapter presented the newly developed service robot called Hobbit. We built Hobbit with the purpose of assisting older adults and to improve their perceived feeling of safety at home. The ultimate goal is to make users stay longer in their homes by using new information technology and new solutions such as smart environments (including ambient-assisted living (AAL)). Besides fostering the feeling of safety, we also set out to improve the feeling of self-efficacy, that is, one's own ability to complete tasks. We set out to achieve this by providing a rich set of functions to the user. We provided methods for emergency detection including the patrolling to regularly locate the user and start an interaction and the detection of emergency situations as a means to directly react if needed, and we provided proactive functions to avoid falls in the first place. These measures included to keep the floor free of clutter, to transport items so the user can walk with hands free, a set of fitness functions to stay active with cognitive and physical exercises and the option to freely set reminders, also with the idea to stay as active as possible.

After the summary of the questionnaires highlighting the functionality, safety and operation features that older adults would want, we presented the Hobbit platform and its technical components. We then presented details of the results of a longer study of the Hobbit robot in the wild—in the homes of 18 older adults. The study lasted for 3 weeks each. Another specific highlight of the study was that the robot was navigating autonomously, a difference to other present robots operating at home.

Of particular interest in the user trails was that the users could freely select what they wanted to do with the robot. This is a considerable change over other studies, for example, with robots such as Kampai or Care-O-bot, where the sequence of trials is scripted and repeated at a set times. An example is the reminder to drink, which in a single test run may be fun for the user; however, the repeated reminder to drink will be rejected by users. In the free setting, this is different, since users select what they would want. For example, users set the reminders all by themselves or with the help of the person.

In conclusion, the mutual care (MuC) concept, which has been proposed to foster the acceptance and improve the use of robot, has been detected to have rather little consequence. A cause for this unexpected result may be with high probability that the technical functioning of the robot is not yet high enough. Hence, there is considerable work ahead. While the trials indicate a first proof of concept, there needs to be more added reliability of all the robot operations. The good finding is that navigation is autonomous and with a service rate of over 98% was rated as sufficient by users. Hence, we provided a very good start for gaining acceptance by the users. This all indicates that reliability is a prerequisite for user acceptance. It will take next steps to work both on the hardware and the software to reach a higher level of reliability not only for navigation but also the other functionalities. Of particular interest are approaches that cope with automatic calibration of sensors, actuators and the sensor-actor combination. This encompasses the mobile platform and the sensors for navigation as well as the active head and the mobile manipulator. It also includes the reliable detection of drivable floor. As many of these capabilities could be reached with adequate software, it will strongly add to the cost-effective concept provided by the Hobbit platform as presented here.

Another important aspect of Hobbit is the HRI. Considering that it should be effective, our main insights are that the active head proved to be paramount to present information about the robot status and, thus, it facilitates HRI in itself. Furthermore, the active RGBD sensors of the head drastically enlarges the field of view of the otherwise restricted camera, and it serves several robot functions for navigation, search and grasping objects. Actually, the active head was found as the key element of intuitive and easy-to-use HRI: the head viewing direction directly indicates what the robot is doing. Augmented with verbal output, the robot lets the user always know what it is doing, and for the user, it is obvious when she can address the robot or not, because it is busy when looking down. Additionally, the adaptive approach to the user and the direct facing of the user create attention: the user knows that now the robot is ready to be addressed and accept the next command. In summary, it would be good to give active robot heads more attention. Remember, as depicted in **Figure 6**, users wanted a head. It is the obvious part of the robot to speak to. Hence, it largely facilitates HRI. To be more fluent, it should be given more research and development work. Furthermore, increasing head range to even look back may alleviate the need for sensors in the back and further increase safety aspects.

To conclude, the Hobbit study in the wild shows a mixed picture. While certain functionalities such as grasping objects from the floor and searching for objects do not provide sufficient reliability, other functions such as navigation, docking, entertainment, reminders and the fitness function proved to be very useful and welcome by the users. Users saw the great potential of such a robot: the capability to pick up something from the floor and to transport and find objects is very highly evaluated. They would not want a cheaper robot with reduced functionality, e.g. without an arm. It is rather that they would want a few more functions such as searching for objects.

6.1. Future developments

These results clearly give advice for future research directions. The robot hardware itself needs to be drastically reduced in size, rather 40 cm in diameter than 56 cm in the diagonal. The robot height should be slightly reduced to 120 cm. A height has been nearly reached to good effect in Hobbit. The only other robot with this height is Pepper at present. Other robots are higher. The smaller robot size will also make it easier to navigate in the typically tight spaces in the homes of older adults.

Based on the results from the questionnaires and interviews, the reminder functions, picking up objects and bringing objects, are all highly validated by users and thus need to be considered as high-priority user requirements. Picking up objects and bringing objects need an arm and some sort of gripper. Users wanted the gripper and saw, in particular, the advantage of picking up things from the floor.

There are a few other clear misses in the present Hobbit robot. One that most users would want is a speech interface. It clearly needs to be part of Hobbit's user interface. Speech recognition and output therefore need to be state of the art, without ignoring the final objective of the project of affordability of Hobbit. The technical problem at present is distant speech recognition. While speaker into a headset or the mobile phone provides good recognition results, a microphone mounted on the robot, the large distance to the user and the noise of the robot itself are all factors to limit speech recognition drastically. While on the one hand an improvement of distant speech recognition can be expected, another option may be to equip Hobbit with a mobile phone as a natural interface to the robot. While considerations for this solution have been made, the main issue to solve is that the mobile phone could be replaced. Hobbit will need a functionality to search for it using RFID chips and sensor or other means.

Another aspect that is of need for future developments is an adaptive behaviour from Hobbit. Depending on the preferences of the user (i.e. an individual user profile), the amount of autonomous, proactive behaviour of the robot needs to differ. Ways of adapting to the user profile are to be developed for every function from approaching the user, to the times and frequency when the robot should approach the user. Ideally, this is learned from the first trial interactions. Though, this will require substantially more research and improved capabilities of the robot to fully understand the user.

Finally, the Hobbit study with letting the robot be operated with any prescripted operations showed that older adults are indeed very interested in new technology and that a robot at home has very high potential. Although the present price tag may be too high, users clearly indicate that the full functionality is of the highest value and should be pursued in further developments.

Acknowledgements

This research has received funding from the European Community's Seventh Framework Programme under grant agreements No. 288146 Hobbit and No. 610532 Squirrel and funding from the Austrian Science Fund under grant ALOOF No. I1856-N30. Thanks to Andreas Bley of MetraLabs for the picture of the robot docking station.

Author details

Markus Vincze*, Markus Bajones, Markus Suchi, Daniel Wolf, Lara Lammer, Astrid Weiss and David Fischinger

*Address all correspondence to: vincze@acin.tuwien.ac.at

Technische Universität Wien, Vienna, Austria

References

[1] Das D, Rashed MG, Kobayashi Y, Kuno Y. Supporting human-robot interaction based on the level of visual focus of attention. IEEE Transactions on Human-Machine Systems. 2015;**45**(6):664-675

[2] Rebecca E. Grinter Ja-Young Sung, Henrik I. Christensen. Robots in the wild: Understanding long-term use. In: ACM/IEEE Conference on Human Robot Interaction (HRI). 2009

[3] Leite I, Martinho C, Paiva A. Social robots for long-term interaction: A survey. International Journal of Social Robotics. Springer, 2013;**5**(2):291-308

[4] Hanson VL. Age and web access: The next generation. In Proceedings of the 2009 International Cross-Disciplinary Conference on Web Accessibililty, ACM, pp. 7-15, 2009

[5] Astrid Weiss, J. Beer, T. Shibata, and M. Vincze. Socially assistive robots for the aging population: Are we trapped in stereotypes? In Proceedings of the 9th ACM/IEEE International Conference on Human-Robot Interaction, 2014

[6] Markus Vincze, David Fischinger, Markus Bajones, Daniel Wolf, Markus Suchi, Lara Lammer, Astrid Weiss, Jürgen Pripfl, Tobias Körtner, and Christoph Gisinger. What older adults would like a robot to do in their homes - first results from a user study in the homes of users. In: IEEE International Symposium on Robotics ISR, 2016

[7] Lammer L, Huber A, Weiss A, Vincze M. Mutual care: How older adults react when they should help their care robot. In: . Proceedings of the 50th Annual Convention of the AISB; 2014

[8] Pripfl J, Körtner T, Batko-Klein D, Hebesberger D, Weninger M, Gisinger C, Frennert S, Eftring H, Antona M, Adami I, Weiss A, Bajones M, Vincze M. Results of a real world trial with a mobile social service robot for older adults. ACM Digital Library. 2015

[9] Fischinger D, Einramhof P, Papoutsakis K, Wohlkinger W, Mayer P, Panek P, Hofmann S, Körtner T, Weiss A, Argyros A, Vincze M. Hobbit, a care robot supporting independent living at home: First prototype and lessons learned. Robotics and Autonomous Systems. 2016;**75**(Part A):60-78

[10] Yardley L, Beyer N, Hauer K, Kempen G, Piot-Ziegler C, Todd C. Development and initial validation of the falls efficacy scale-international (fes-i). Age and Ageing. 2005;**34**:614-619

[11] Huber A, Lammer L, Weiss A, Vincze M. Designing adaptive roles for socially assistive robots: A new method to reduce technological determ stereotypes. Publication in the International Journal on HRI. 2014;**3**(2):100-115

[12] B. Pierce, T. Kuratate, C. Vogl, and G Cheng. Mask-bot 2i: An active customisable robotic head with interchangeable face. In: IEEE-RAS International Conference on Humanoid Robots (Humanoids), 2012

[13] Ross Mead and Maja Mataric. Robots have needs too: People adapt their proxemic preferences to improve autonomous robot recognition of human social signals. In: New Frontiers in HRI Symposium, AISB, 2015

IntechOpen