What a Year of Trials with a Mobile Robot in User Homes Reveals about the Actual User Needs

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Abstract. Although there are great studies of what robots should deliver, there is a large discrepancy between what services robots can provide and what users would want them to deliver. To a large extent this is also the fault of preconceptions users have from literature, films, or other media that is rather misleading about the capabilities of present day robot technology. We use a study with a robot helper set free in 18 user homes, to report barriers to marketing robots structured in practical, technical and conceptual factors.

1 Introduction

Although there have been considerable efforts towards a robot to assist older adults to stay longer independent at home, a robot helper or even companion would still require substantial research, development and engineering effort. We contributed with the Hobbit robot a relatively low cost robot variation with several assistive functions such as picking up objects from the floor, searching for objects, and a series of fitness and entertainment functions. The user trials extended over a total of 371 days with 18 user, where the robot could be tested in the wild, i.e., in the home of the users. Since we did not give any predefined use scenarios, the trials gave considerable insights into the barriers between the actual status of today's robots and what the users expect. The insights also deviate from findings in previous studies, where tasks have been defined for every day and users had no free choice to select what they want the robot to do.

The contribution is to use this extensive study of robots set free at home to list barriers for introducing a home robot to the market for the support of older adults. In essence, barriers comprise practical, technological and conceptual key factors. Practically, there are hardly any studies of what users really want from robots. And when asked without given reference to what technology may provide, results are rather wishful thinking than realistic, indicating cleaning the bathroom, kitchen, toilet and windows, which are all not yet feasible, e.g., [1–3]. Technically there is a lack of robust approaches both regarding the robot hardware as well as software methods in the challenging environment. And conceptually there is a discrepancy between researcher and user expectations:

users rather want a helper or pet to keep them active rather than a companion replacing human contact. And users expect predictable robot behavior for a few assistive functions such as picking up objects from the floor that is yet difficult to achieve.

1.1 Related Work

There have been rather few studies of robots in user homes besides the studies with small robots, e.g., [4–6]. However, these are single task robots and far from a home or social robot. Larger robots have been extensively tested for example in the SRS (MultiRole Shadow Robotic System for Independent Living) project, where work focused on the development of remotely-controlled, semi-autonomous robotic solutions [7]. The robot was too large and was tested in care facilities rather than homes. Predefined scenarios with fixed locations to the user show that users like help from the robot, even for drinking reminders. In other projects, such as Giraff++, the robots were also externally teleoperated [8] and there was no autonomous navigation. In the Companionable project, autonomous navigation to fixed predefined places was incorporated, but a controlled test home was used [9] instead of different real home environments. The projects gave hints on interaction modalities, though the practical results mostly indicate touch screen.

One of the longest tests of mobile robots in user homes have been carried out in the DOMEO and SERROGA projects. Domeo used scripted tests in six households with Kompai of Robosoft, though it speaks by itself that the company does not exist any longer. SERROGA autonomous navigation towards fixed predefined goals was tested in twelve real homes of staff and senior users. In this case the robot was left with the users for up to three days. Tasks have been set for every day.

Enumerating these studies, it becomes evident that the basic functionality of robots including reminders, entertainment, plus some physical help, is worth testing in free setting and directly with older users in their own homes.

2 Barriers for Home Robots

To obtain a better understanding of what users actually expect from a robot, we conducted extensive user trials with a robot that has been empowered with a reasonable set of functions. The Hobbit robot is depicted in Figure 1.

Hobbit was designed to be considerably more cost effective than other robots with the aim to present users with something close to what could be expected for first commercial robots. Still a cost of 15.000€ is high, still gain astonishing approval, if core functionalities would be provided.

A series of entertainment functions such as listening to radio or books, a physical fitness application, games, and communication functions, and physicial support functions such as grasping objects from the floor and and searching for learned objects (for more details refer to [10]).

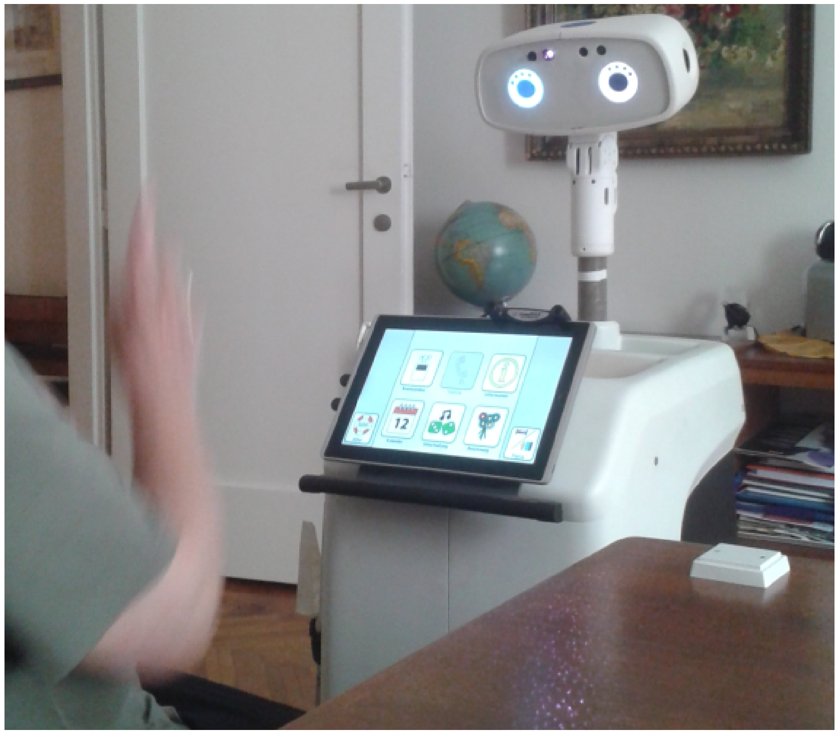

Fig. 1. The Hobbit robot facing a user. The active head is used to clearly indicate to the user when the robot expects input. On the right side of the body a part of the gripper and robot arm is visible. On the table is a battery-less call button to initiate interaction with the robot.

Users could freely select what to do and have been questioned on what functionality would help them to stay longer at home and live independently. The challenges for the evaluation of the trials is to guarantee autonomous interaction between user and robot without the presence of an influencing observer. To moderate these difficulties of gathering data while leaving the user as free as possible, multiple methods have been applied to obtain data. The mixed methods approach included:

- Qualitative measures: interviews, conjoint analysis, cultural probing.
- Quantitative measures: questionnaires, logging data.
- Repeated evaluation: most of those measures were assessed four times for each primary user (PU): beginning (pre), midterm, end-of-trial, after (post) trial. Logging data were collected continuously.
- Besides PU, SU were asked for their attitudes and opinions at the end.

Using the results of 371 days of robots in the actual homes of older adults and a multi-factor analysis of their expectations and responses to alternative test materials, the contribution of this work is the analysis of the user robot relationship and how users see this after using the robot at home. Specifically we extracted conceptual and technological factors that indicate which barriers need to be approached to bring a robot to the market that helps older adults to stay longer independent at home.

2.1 Practical Barriers

The evaluations as well as state of the art indicate three, what we refer to, practical barriers: (1) on reasonably well-operating robot platform, (2) robot costs and (3) coping with the challenging home environment.

When scrutinizing the presentations at recent social robot conferences, for example, HRI 2017 in Vienna, the majority of papers is based on Wizard-of-Oz studies. While in themselves they may produce relevant findings, the picture is clear: as of today, robots do not live up to what users expect. This directly links to technical barriers (see below). But it also indicates that it is not yet clear what robot functionalities constitute the first entry point for home and social robots. Also compare to the studies referenced in the beginning, which largely speak of cleaning functions the robots are far from fulfilling.

What researchers and people interested to commercializing robots could conclude from this is that, at present, a social robot is not achievable. This is countered with the clear potential, in particularly for older adults and the challenge of the aging population. Users clearly indicated this in the Hobbit trials, for example: "I can imagine that, as a result of having a robot, it would be possible to live at home for a longer while. He would need to access all rooms in a flat." The last part actually refers to one more barrier, present mobile robot platforms are often too large for use in private homes.

The second obvious practical barrier is the present *cost of a home robot*. The research platforms that are used in larger projects are more than a magnitude away from costs that are potentially acceptable for first adopters. The results in the trials with Hobbit indicate two directions. The cost of a robot in the range of a lower price car is acceptable and users would rather rent than purchase the robot. The reason is that it is not clear for how long users would need the robot.

Furthermore, we conducted a study to obtain indications where to possibly reduce the cost of the robot. Table 1 gives the results. In the study we did not ask directly for the prices given, but used a component analysis to indicate price range with a comparative, well known item such as high end computer, screen, or a pair of shoes.

In a second study on costs we asked users for preferences of full or partially reduced functionality. Results confirm the indication from the Table. A Hobbit robot with head, pick-up and learning functionality for 15.000€ would have the highest market potential based on the data by users. There is no simple entry point.

Finally, the home environment is challenging. While the issue here could also be listed under technical barriers, we think that simple practical challenges of the home setting still wait for solutions. The most imminent challenge are thresholds, uneven floors, loose carpets, etc. With Hobbit we used rubber ramps to level

Table 1. What users would be willing to pay for robot upgrades in relation to a robot platform for about 3000€ (all prices give an indication using a comparative study). While cheap buttons to call the robot are obviously top in the list, an arm at the same cost of the platform itself would be wanted by more than half the users. This result weighs even stronger given, that the arm worked only about half the time.

	V1	V2	V3	V4	V5	V6	V7	S1	S2	S3	S4	S5	S6	S7	G1	G2	TOTAL
Bottle (100 €)	No	No	No	No	Yes	Yes	No	No	No	No	No	M'be	No	No	yes	No	22%
Arm (3000€)	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	M'be	No	No	No	Yes	53%
Tray (200€)	Yes	No	No	Yes	No	Yes	No	No	Yes	Yes	No	M'be	No	No	Yes	No	40%
Learning tray (400€)	No	No	Yes	No	Yes	No	No	No	M'be	No	No	M'be	No	No	No	No	18%
Head with face (1500 €)	No	No	No	No	No	Yes	No	Yes	Yes	No	No	M'be	No	No	Yes	Yes	34%
Call button (20 €)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No	No	Yes	Yes	75%

out thresholds as depicted in Figure 2. The second important challenge are narrow spaces (Figure 3). Older adults naturally accumulated items. Additionally, doors are often not more than 0.7 m wide, which was particularly encountered in Sweden. It is these practical issues that studies in labs, care facilities, or special homes do not address at all and hence add to the discrepancy of a robot at home vs. studies in controlled settings.

Fig. 2. Examples of ramps to overcome thresholds. Sometimes fixed with tape, which is certainly not wanted for permanent installations by users.

2.2 Technical Barriers

Technical issues largely concern bringing robot techniques to the market on a rather low cost platform and in the challenging home environment with largely varying settings as mentioned above. The analysis of the deployment of the Hobbit robot in 18 homes includes the following factors. We highlight in this contribution the barriers, while in [11] interested readers find a more complete account of lessons learned regarding primarily technical issues.

Fig. 3. Two example of narrow doors of 0.7 m in homes of two Swedish users. The robot is 0.56 m wide and should be slimmer.

A key factor is predictable robot behaviour. Researchers or engineers often stress robustness of methods and approaches. While robustness is part of the game, users are even more concern that the robot always does what is expected. It might fail at one point. Users understand this but expect that the robot report this and users are, in general, willing to help [12]. Certainly, a basic level of functionality is required. We found this with Hobbit where a success rate of 98% in navigation was acceptable while missing to detect object half the time was clearly not. But the only time a user stopped the trials was when the robot started to move out of its docking station without any reason or explanation. After the second time, the user did not feel safe any longer. As another user expressed it, the robot should be able to explain what it is doing: "I can't really rely on it. ... I do not always understand what it is doing."

Another key factor is autonomous navigation including the link to semantic information as a user would expect it. As indicated by several projects, for example, Giraff++, there is still no solution that can be taken out of the box to resolve navigation in a private home environment. The main discrepancy is navigation as considered solved with laser sensors for quasi 2D environments. However, homes are very much 3D with protruding pieces of furniture and many different surface properties in complex and narrow settings. With Hobbit these issue could be largely resolved with modern depth cameras to perceive the environment up to the height of the robot and several additions to cope with the smaller viewing angle and observing the confidence in the localisation estimates [13]. However, there is yet no practical solution to automatically map the user's home and give the rooms the names the user will expect to use.

The third important technical factor is the user interface. Touch screens have been mostly used and received good feedback in many studies. However, what users would really want is to talk to the robot and simply give it a command in words. While speech understanding had great progress on mobile phones where users directly speak into the microphone, distant speech recognition of robot platforms remains an open challenge.

While there are more factors (to be discussed at the workshop), let us present one already mentioned: Users would want to robot to be active with at least one arm. The cost and capabilities of arms are far behind what it needs. We see the largest potential for advance in developing low cost, useful mobile manipulators.

2.3 Conceptual Barriers

As a result from the work in Hobbit, we noticed two barriers related to conceptual factors: (1) expectations of researchers vs. expectations of users and (2) a mismatch of robot design.

There is a significant discrepancy between researcher and user expectations. Users clearly indicate a preference for a robot helper or robot pet to make them feel safe at home, to help them with things that get more difficult, and to keep them active - in this order. On the other side is the expectation of researchers to provide a robot companion. However, users are not interested to have a robot companion replacing human contact. Secondary users oppose this conceptual idea even more. The consequence could be revisiting research goals. Users would first expect little companionship, rather real help and providing basic functionality to feel safe. Maybe when these steps have been reached, other functionality is welcome.

As last gap, we present a result of workshops with over 100 older adults in Sweden and Austria, where in an open process robots where designed rather than assessed. The result is striking when compared to Hobbit or other robots. Figure 4 gives a few examples of how users would want the robot to look like. There is large scope for improvement. Users are happy to show that the robot is a clever piece of technology and do not ask for a humanoid. There is room for improvement such as materials could be softer yet washable, the robot's appearance more friendly, and robot functionality is expected with two arms.

3 Conclusion

In this contribution we tried to summarize experiences gained in a large user study to indicate barriers for a home or social robot to reach the market. The study lets us conclude that there are practical (costs, challenging home environment, and a first working platform), technical (navigation, speech, mobile manipulators, etc.) and conceptual barriers (the discrepancy between what researchers believe is needed and the yet not really known user needs).

The goal of this summary is manifold. First, we hope to raise further discussion on this important topic for robotics and more clearly see what is missing. Second, the findings shall indicate future directions for research. And third, we might consider anew how to study what users want. There is a clear discrepancy between open studies (cleaning as primary target), studies with social interaction

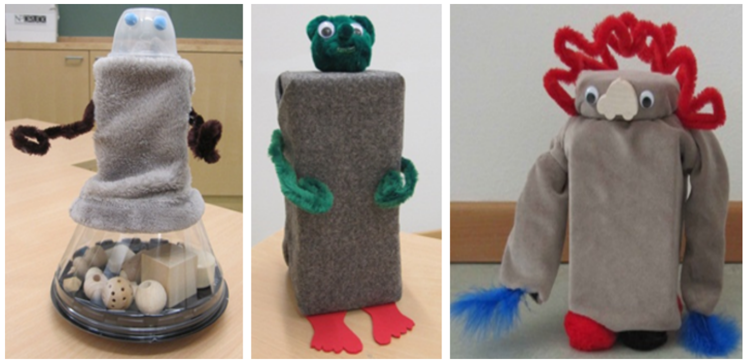

Fig. 4. Three examples of robot models build by older adults that clearly indicate the discrepancy between what technology at present provides and what users would want.

(indicating the need for a companion), our study with robots in homes in three countries (indicating rather a pet-like relationship with a few care functions for the robot), future studies that overcome obvious limitations to motivate users to be active, and long term studies that may again change our impression of how humans treat robots.

In all this debate, lets us conclude with the voice of a user. The potential of a home robot, not only for older users, but for them in particular, is enormous. To let a user speak: "Hobbit is an inspirational tool. ... The robot could increase the quality of life. I live alone and the robot is like a treasure."

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