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A LIGHTWEIGHT, USER-CONTROLLED SYSTEM FOR THE HOME

Lynne Baillie
Telecommunications Research Center, Vienna
Austria

Raimund Schatz
Telecommunications Research Center, Vienna
Austria

Abstract: *This paper explores how we designed, with input from some elderly persons, a multi-agent user-controlled network for the home. The system was designed to support the elderly in living longer at home with minimal support. We describe how our work attempts to tackle issues such as privacy, control of personal space, and enjoyment within the home. As the number of elderly individuals' increases, a certain amount of information gathering or support may be required to assist the elderly in their homes. However, we strongly believe that we should preserve people's privacy in their homes and ensure that any artifact we propose is seen as enjoyable, aesthetically pleasing and, most importantly, not stigmatizing. We describe in this paper how a lightweight setup, using a multimodal mobile robot, a PDA, and an interactive television, can assist the elderly in the home in an enjoyable and unobtrusive way.*

Keywords: *interactive television, ubiquitous computing, information interface, elderly.*

INTRODUCTION

The aging of Europe's population (by 2020, more than 25% of Europeans will be aged 60+; Lutz, O'Neill, & Scherbov, 2003) will have a dramatic effect not only on our societies but also on technology and product development. This trend will influence the design of high-tech commodities and information and communications technologies (ICTs), such as mobile devices. In addition, the desire of older people to live in their own homes and the decline in institutional living, will drive a growing demand for solutions that allow for aging in place[1] (Corso, 1977). Home solutions based on mobile and stationary ICTs (such as our proposed system) have the potential to satisfy this demand by aiding people in coping with everyday life and supporting their integration into society.

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The Telecommunications Research Center (Forschungszentrum Telekommunikation Wien [FTW]) in Vienna, Austria, is involved in various scientific endeavors, one of which is to investigate and develop multimodal interfaces for mobile devices for next-generation telecommunications. Several partner companies of FTW were interested in building a lightweight, user-controlled network for the home. They envisaged a quite utilitarian design for this environment, which would borrow ideas and elements from existing "smart" homes and similar environments. In contrast to this vision, however, some user-centered design experts believe that technology for the home should be part polemic, part science, part serious, and part fun (Norman, 1988).

Therefore, a better solution for low-level home monitoring[2] may result from undertaking user studies and gaining experience and knowledge from elderly people in their homes. We would like to mention at this point that we did not intend for our resulting design or system to be used by people who have high care needs. This can be done much better with a system of the type suggested by Dewsbury, Taylor, and Edge (2002).

AGING AND TECHNOLOGY

Researchers have found that old age can be split into three stages: young-old age, middle-old age, and old-old age (Namkee, 1999). These stages are less defined by chronological age and more by various social, physical, and mental characteristics. People in young-old age (approximately aged 65-74 years) retire from their work lives and begin to show the first signs of physical or mental weaknesses (e.g., memory problems) even though they are still quite active. People in middle-old age (approximately aged 75-85, equivalent to Peter Laslett's [1998] third age) are still active and quite independent from others. However, impairments or chronic illnesses drive the need for supportive technologies. Old-old age then follows, when weaknesses become so predominant that a person's everyday life is highly dependent on external support from people and technology.

In this context, telemonitoring is an area of growing interest for the Western world's aging societies, as it enables people to live in their own homes for a longer time, rather than having to move to a medical facility or care home (Dishman, 2004). The raison d'être of most telemonitoring projects has been to support patients and care workers in monitoring a life-threatening (Benatar, Bondmass, Ghitelman, & Avitall, 2003) or chronic illness (Giraldo, Helal, & Mann, 2002). One of the main issues in this work is that telemonitoring systems require multiple sensors, devices, and complex network setups (Lukowicz et al., 2002; Sachpazidis, 2002). A benefit can clearly be seen for employing technology with this level of complexity and pervasiveness when the purpose is to monitor patients who have chronic or life-threatening diseases, but the rationale is less persuasive when the person has only low monitoring needs. It could be argued, therefore, that the social aspects of the home must be integrated into the development of supportive home systems.

So far, most research initiatives in the area of supportive technologies for the elderly in the home have been restricted to solutions for discrete narrow-age segments with specific needs, for example, people with severe disabilities and heavy monitoring needs (Lukowicz et al., 2002; Sachpazidis, 2002). However, gerontologists see aging less as a staged sequence and more as a continuous, incremental process (Dharmarajan & Ugalino, 2000), which is characterized by (a) gradual loss of skills—motor, sensorial, cognitive skills (e.g., memory), (b) increasing frailty and (chronic) illnesses, (c) increasing social exclusion and problems of isolation.

Therefore, a home monitoring system should support people seamlessly through all three stages of old age by gracefully adapting to people's highly individual lifestyles, patterns of increasing frailty, and need for support. This is especially important given that it has been claimed (Carmichael, 1999) that designers of products and services tend to patronize and stereotype the elderly, treating them as a homogenous group. In this sense, a truly useful home system should be adaptive, modular, and lightweight.

TECHNOLOGY AND THE HOME

A large number of projects in the area of supportive smart environments tend to permeate homes with pervasive technology. In these approaches, one can see a tendency towards challenging users' abilities with overly complex, hard-to-use devices, as well as interfering with their need for privacy. In contrast, Weiser (1991) proposed a calm technology approach to a more low-level system that supports aging people in their homes. The central issue to remember is that no system should swamp people. People can become anxious and worried at the thought of technology surrounding them and invading their home environments (Baillie, 2002). We should be aware that, in the main, a technology should merge harmoniously into the background of the home and support the user in undertaking tasks. These issues are considered in more detail in the following subsections.

Aesthetics

The attachment we have to artifacts in our homes, and how this can affect the use of such artifacts, has been highlighted by Csikszentmihalyi and Rochberg-Halton (1981). They found that three modes mediate the relationship between an artifact and a person: aesthetics, attention, and goal. The importance of aesthetics has also been found in studies of elders in the home. For example, Hirsch et al. (2000) conducted a study of the elderly and their use of artifacts in a retirement village in the United States. They found that artifacts such as rails to help the elders in their bathrooms were being used as towel racks, as the elders did not want to be viewed in a certain way. They also found that motorized wheelchairs were being shunned in favor of motorized buggies. Why? Because buggies were associated with golf and leisure pursuits, and wheelchairs with creeping old age. Therefore, it could be that having something enjoyable like a robot with a camera undertaking surveillance of the home may be seen as more enjoyable, aesthetically pleasing, and less obtrusive than other artifacts, such as fixed video cameras, monitors, and sensors on the walls.

Control

The issue of privacy and control of space in one's home is important; indeed, it has been commented that architects often forget the importance of spaces in the home and the roles they play (Shapiro, 1998). Rosselin (1999) gives the example of a young student's apartment that had no hallway. The student placed a one-square-meter carpet on the floor beside the door, to suggest a hallway, where guests had to leave their shoes, therefore, making what was one space, the living room, into two spaces, the hallway and living room. How can this ownership and control of space impact our use of our artifacts? Silverstone and Hirsch (1992) thought that technology in the home posed a whole set of control problems for households, such as regulation and control of spaces in the home at different times by different people. Feelings of control or lack-of-control were found to be an important indicator of the participants' feelings towards certain spaces in their homes and the artifacts they contained (Baillie, 2002).

Privacy

Do the assistive technologies and devices that are being proposed for people with disabilities or for elders take into account feelings of loss of privacy? It would seem that people may be willing to give up some of their privacy in order to gain tangible benefits. By putting intelligent devices into peoples' homes, we are opening up the possibility for people to be monitored remotely. Rather than hide or try to camouflage this information gathering from users, it could be much more reasonable to be open about this aspect of the device and let the user control it. People are aware that these devices collect information about them (Baillie, 2002; O'Brien, Rodden, Rouncefield, & Hughes, 1999) and are happy to let them do so in certain circumstances, such as to reveal their health status to trusted persons or to summon help in an emergency. In addition, the possibility of sharing information about their well-being with trusted persons remotely can provide great value for the elderly people and their relatives (Dishman, 2004).

The background research has highlighted a couple of issues that designers should consider when designing artifacts for the home:

(a) That any technology, along with all the usual usability goals, should be aesthetically pleasing and enjoyable to interact with;

(b) The user should feel a sense of privacy and have control over any technology proposed for his/her home space.

THE HOME STUDIES

We undertook three home studies, known collectively as a Home Workshop, involving three households in central Scotland (a full description of the study and its results can be seen in Baillie, 2002). The focus of these studies was to gather requirements for future systems for the home.

Methodology

The home studies focused on what technologies the households currently used but also went further and tried to discover what the individuals wanted for the future. The format of the home visits can be seen in Table 1.

Table 1. The Methods and Focus for a Home Workshop (Baillie, 2002, p. 88).

	Focus	Methods
Home Workshop	Investigate current problems and future possibilities	1.Technology tour 2. Representations of emerging technologies 3. Scenarios 4. Sketches

Undertaking a study in the home was seen as an opportunity for the researchers to learn about the households and the technology contained within them. This was achieved by carrying out a “technology tour” (Baillie, Benyon, Macaulay, & Petersen, 2003), the aim of which was to collect information about existing technologies. The technology tour involves householders taking the researchers on a tour of their homes. Several researchers have pointed out that the way in which technology is integrated into the physical and social organization of the home provides useful clues to understanding the use of technologies (O’Brien & Rodden, 1997; Venkatesh, Shih, & Stolzoff, 2000). Thus this focus was maintained in the technology tours as the researchers asked about possible conflicts in ownership of the space (O’Brien & Rodden, 1997; Venkatesh, 1996) at different times by different family members, as well as the history, flexibility, and motivation for the physical organization of technology within the space. The researchers asked the participants to describe problematic situations they had experienced with their technologies and to show how they used the technologies (Sperschneider & Bagger, 2000). The main thrust of the technology tour revolved around four key issues: what technologies are present in each room, where they are placed, who uses these technologies, and how they are used.

The participants were then shown emerging devices with the aim of stimulating discussion about future devices. The devices included things such as the refrigerator that “knows” when it is out of milk, the microwave oven with e-mail and an i-link (enabling users to link-up various devices, such as the TV, sound system, PC), and so on. This was so that the discussion was not limited to currently existing devices but was also looking towards the future and what might be available in 5, 10, or 15 years.

We then discussed possible future scenarios of use. For example, we asked them to imagine waking up in the morning and having available an assistive system. What could they imagine it doing or how could it assist them? Scenarios can be used to facilitate the creation of sketches and more involved user participation in the development of a design. In addition, scenarios can be as flexible, informal, sketchy, or as structured as needed.

Finally the participants were asked to sketch a future device for the home that they would like to have. There were three reasons why they were asked to envision their own technology for the home. First, home technology at the moment is mainly built and designed from the manufacturers’ rather than the user’s perspective. Second, it was hoped that by asking the participants to think of their own solutions it may help them and us to envisage some novel ideas for designs. Third, the sketches would provide a way of extracting and learning about the needs and wishes of the participants and could help some of the more diffident participants to create an overflow in their imagination, as described by McKim (1972). Therefore the home session was split into four separate but overlapping parts.

Procedure

Each household was visited on three occasions at mutually convenient prearranged times. The households involved can be seen in Table 2. Pseudonyms have been used for the participants.

While it could be claimed that the Cooks were too young to take part in a study about a system designed for the elderly, we thought that it was important to include them, as they would soon be reaching retirement age (in Scotland, the retirement age for women is 60 and 65 for men). It was anticipated that they would be able to provide information on new retirees who may be more technologically knowledgeable. The other participants could be said to meet

Table 2. Households Involved in Requirements Gathering.

Identifier	Who		Age	Occupation
Cooks	Robert	Husband	60	Senior lecturer
	Sue	Wife	55	Housewife
Suttons	Emily	Wife	70	Retired teacher
	Peter	Husband	72	Semi-retired builder
Reilly	Agnes	Widow	84	Retired cook

the criteria of middle-old age. Equipment taken to the homes for the interviews comprised a video camera, pens, paper, art materials, and a notebook.

Findings from the Home Studies

A very small selection of the sketches (drawn by the participants themselves) and comments made by the participants are presented in this section. In the sketches, the control issue was elucidated by the participants wanting to know more about what was going on in their homes and who was "in" them when they weren't there. The concept of security spanned further than securing the home from burglars, by also encompassing the well-being of family members and the ability to contact the emergency services. For example, Agnes wanted her device to be used in the event of a fire or an emergency. She anticipated that the system could be accessed by the emergency services to let them know who, if anyone, was in the building (see Figure 1).

Agnes also wanted her device to enable her to see and monitor her home when she was not present. The idea of the device came to her because of her frustration about not being able check on her home when she went on a holiday in the United States. She made it very clear that only she should be able to control the access to the monitoring system for her home.

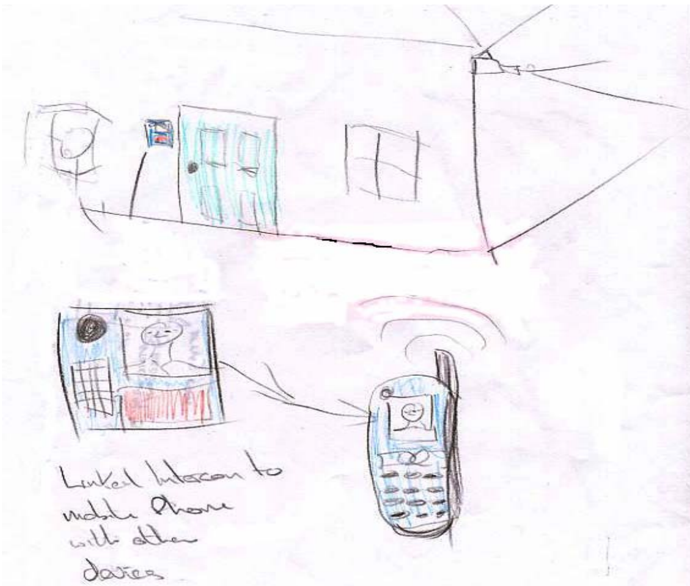

Figure 1. The device concept drawn by Agnes is a remote home monitoring device.

Meanwhile, Peter wanted a device (see Figure 2) that would alert him if he had left devices on in a room, for example, the television, cooker, or lights. He mentioned that he was becoming forgetful and that he would find a device of this type very useful. He felt very strongly that he did not want an artifact taking up space and dominating his home. Peter also remarked that if the other houses on his street were wired to this system, they could have a communal warning and message system to aid communication.

Some researchers have suggested that people may benefit in unanticipated ways from linking homes and private spaces in this way. For example, Blythe, Monk, and Park (2002) suggested that social connections, which have been lost over time, could be reactivated by using local on-line street maps that would help householders keep in touch with their local surroundings and chat with neighbors. The fact that a senior citizen designed a device that would help him as he grows more infirm and forgetful is of interest, as many researchers at the moment are looking at building smart homes and trying to understand what senior citizens would want from this type of home. Therefore a clear benefit to researchers and to senior citizens can be seen if the designer/researchers involve senior citizens in the actual design process rather than only thinking of them as a source of data.

In our home studies, the seniors also mentioned that they did not want the monitoring system to be too utilitarian or stigmatizing. Peter wanted one of the interaction devices to hang on his wall like a picture. He wanted the functional interface to disappear when not in use and a photograph of his daughter and grandchildren to appear. Agnes thought "those funny dogs from Japan" (AIBOs) would be a good idea. Our home studies demonstrated that

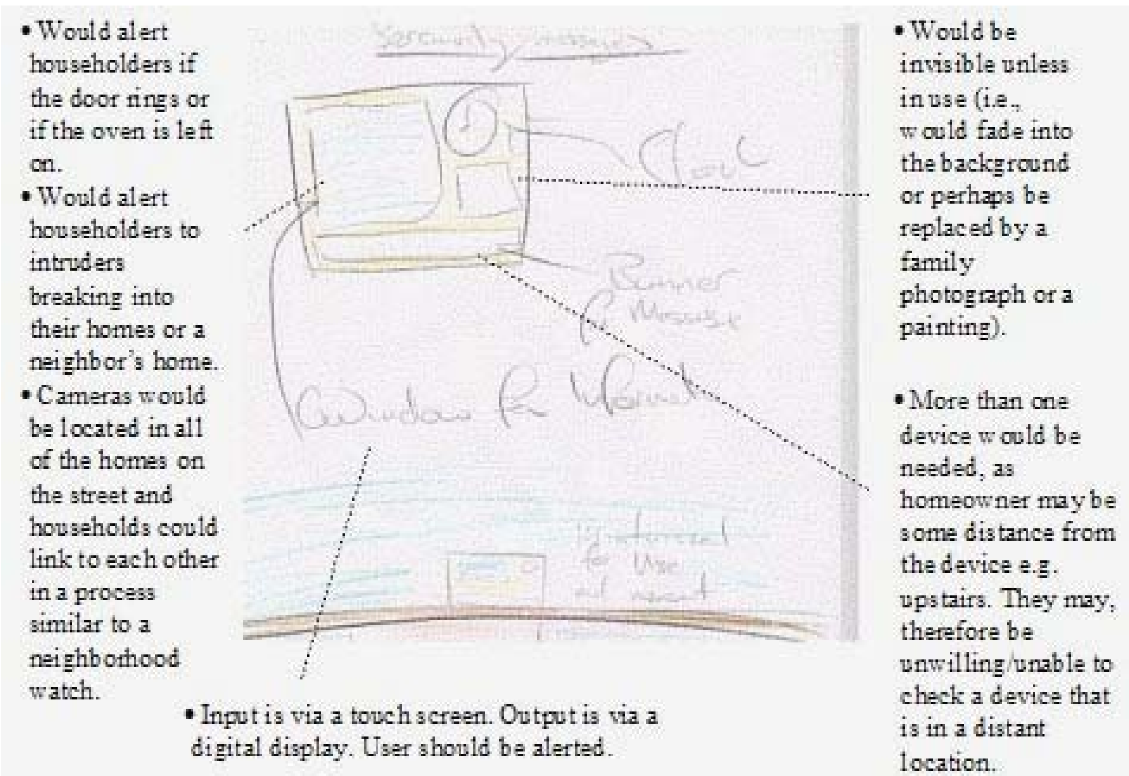

Figure 2. The device concept drawn by Peter.

the elderly were quite capable of coming up with new and interesting ways in which their homes could be monitored without the need to install permanent cameras and sensors, which could be seen as obtrusive and not in harmony with the aesthetics of the home.

The findings from the studies led us to believe that a device that would provide some level of home monitoring would be more welcomed by users if it had the following attributes:

- It could be accessed and controlled remotely, either via a mobile device or the Internet;
- It was unobtrusive (merged into the background) and did not take up space in their home or affect its fixtures or fittings;
- It allowed for privacy and its control rested with the householder. The householder would be the only one to relinquish this privacy and control, should he/she wish to do so.

THE PROTOTYPE SYSTEM

While many devices and concepts were envisaged during the development of our prototype system, none could be said to offer all of the wishes expressed by the householders. However, all of the core concepts expressed by the interviewees were used in the design process, meaning the resulting system provided a way in which to monitor a home remotely and in an unobtrusive manner while keeping the control of the system with the householder or whomever he/she decided to give access.

Our design for the system was also influenced by Carmichael (1999), who found that designers tend to patronize the elderly and treat them as a homogenous group. We tried to avoid this pitfall by conceiving technologies that would meet the specific, yet diverse, needs of the elderly.

The findings from our home studies led us to include a mobile device and the Internet in our system, thus allowing the system to be accessed and controlled remotely. Numerous research findings have shown that older adults are interested in the Internet. In fact people aged 60+ are the fastest growing age group on-line (Fox, 2004). In addition, Dewsbury et al. (2002) found that if the elderly are offered a communication aid that doesn't fit into a pocket then they often choose not to carry it. We concluded, therefore, that an appropriate device to meet this condition was a mobile one.

The wish for unobtrusiveness and non-stigmatization led us to include a more traditional technology, the television. There were two reasons for this: The TV is already in most people's homes and our home studies revealed that it was a highly esteemed artifact in the home of our elderly users.

We also wanted to include an enjoyable and lightweight monitoring device to the system. To this end we investigated the possibility of a small robot. We thought that this may be a reasonable solution, as research by Friedman, Kahn, and Hagman (2003) indicated that elderly people felt comfortable using (as well as ignoring) robots and similar devices in their homes. Another reason was that it can easily be picked up and put in a cupboard, thus fulfilling the prerequisites of not affecting the fixtures and fittings and helping the elderly person not feel stigmatized.

Therefore the main elements of the system we developed were (a) a smart device (Smart Phone/PDA) as a mobile assistant, (b) a mobile ambient intelligence unit (the multimodal robot), and (c) an interactive TV set (see Figure 3). These three elements are described in more detail in the following sections.

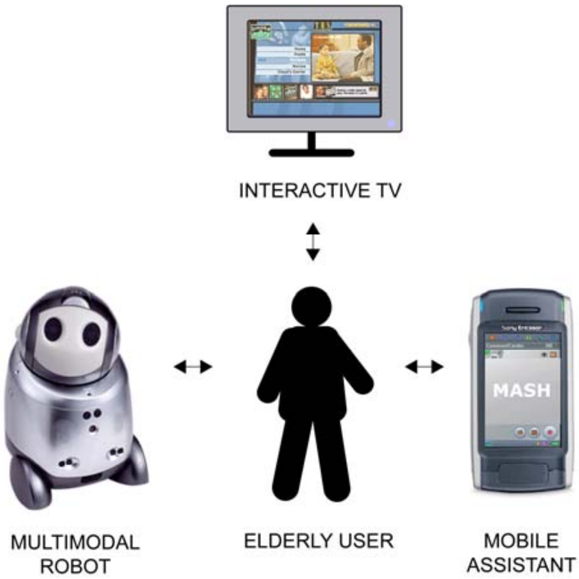

Figure 3. The first concept of the system.

Multimodal Robot

Multimodality promises natural user interaction with devices and applications. Because human communication is multimodal, a device that operates with multimodal communication is perceived as natural and intelligent. These properties are relevant to building easy to use and enjoyable interfaces and applications. The robot was built using the Mindstorms kit (Lego n.d.). The robot can move around and has touch, temperature, and vision sensors, as well as a Web cam. To enable communication between a web server and the robot we installed the Lejos Java Virtual Machine[3].

The behavior of the robot, including the navigation, was implemented according to the behavior control theory by Bagnall (2002). The users can interact with the robot using verbal communication, that is they can give it voice commands such as "go to the kitchen." The users can also control the robot via a multimodal user interface available on their television and a PDA/Smart Phone (the user can choose whether to use a PDA or a Smart Phone).

The interface, as configured for our tests, showed an interactive map of the rooms in the test home and where the robot was located. It was possible to send the robot around the home and let it fulfill different tasks, such as measuring the temperature and checking whether the lights were on or off.

The robot can also function as a watchdog and as the user's remote "eye" in that it can be accessed via a mobile device when user is not at home. Dewsbury et al. (2002) commented that these types of sensors would provide the first level of support to someone who needs a low level of care.

Mobile Assistant

The core purpose of the mobile assistant was to provide the home system with a portable, lightweight interface. Through the Web interface noted above, users can remotely control the multimodal robot independent of their own location. However, today's mobile interfaces (i.e., tiny displays and keys) present serious challenges to elderly people with their more demanding physical requirements. Therefore, voice input and output were provided as alternative modes for our system. Another reason for the inclusion of a Smart Phone in the mobile solution was the need for telecommunication capabilities, for instance, to summon help quickly and efficiently when required. Other research (Dewsbury et al., 2002; Lundell, 2004), as well as our own studies, have shown that elders have no problem with using portable technology that offers assistance inside and outside their homes. Again the design guidelines provided by Carmichael (1999) for the elderly were followed.

For testing we developed an interface for a PDA (see Figure 4). This device allowed a user to control the system using a multimodal user interface that showed a map of the rooms in the test home and where the robot was located. The user could also interact with the system via the TV using the TV remote control.

Figure 4. The PDA on the left shows a map of our mock-up apartment at our research center. The PDA on the right shows the current temperature in the living room of the apartment.

Interactive TV

Studies have found that the television is an elderly person's preferred channel of media consumption and that it is a well-established element in the home environment that enjoys a high level of user acceptance (Andrew, 1999).

In addition to its normal purpose, the television can be used as a large display unit. Using a TV set as an alternative display unit should alleviate some of the problems that people with visual impairments have with mobile devices (e.g., small font sizes, need for scrolling, and low contrast). Also, a TV could help the hard of hearing, as users are familiar with adjusting the volume controls via their TV remotes and TV sets offer surround sound and other sound features. For these reasons, an interactive TV set was included as the third component of the home system. It was additionally anticipated that as an elderly person became more used to the features of an interactive TV, they may in the future use the TV as a communication device (e.g., for video conferencing or Web browsing.)

EVALUATION OF THE PROTOTYPE

We organized a small user test of our system. First, we wanted to investigate whether or not the system could in fact be operated using voice commands and if these voice commands were carried out effectively (i.e., if the user told the robot to "go to the kitchen and check whether I left the cooker on," did the robot indeed go to the kitchen as commanded and report back?). The second part of the study focused on the usability of the system. That is, whether or not the simple tasks highlighted by the earlier home studies could be completed (e.g., turning lights off that had been left on accidentally).

The system was tested at our research center in a mock-up of one of our home study participant's residences (see Figure 5). Therefore, the system did not face a true field test. While a simulated environment would not be the ideal setting in which to test the full system, it was appropriate for undertaking experiments at such an early stage of the system's development.

Figure 5. The robot located in the mock-up living-room at our research center lab.

Aim of the Evaluation

The aim of the user evaluations was to uncover the following:

- Do the users, in general, find the technology attractive and useful, meaning can the system with its various components meet real needs for lightweight monitoring in elderly people's homes?
- Is the technology understandable and easy to operate? In particular, we examined whether
    - o the available functions are immediately perceptible in a way that supports the user's spontaneous understanding of possible and/or necessary opportunities for action;
    - o the user continuously receives relevant and immediately understandable feedback from the interface and guidelines for further action in the course of interaction;
    - o the system supports the user's navigation in such a way that the user always knows where they have been, where they are at the moment, and where they have the possibility to go in the overall information space.

Because the system is supposed to be used by people perhaps unfamiliar with contemporary technologies, employs a range of devices, and performs a wide range of tasks, we consider success in these testing criteria as prerequisites for an enjoyable user interaction. When technology draws on the highly developed human capabilities for immediate perception and comprehension of a large amount of information about the physical world, and exploration and manipulation of this physical world are permitted, the technology has the potential of being a "transparent" tool[4] for information in the course of everyday tasks.

Methods and Procedures

With the aim of uncovering usability advantages as well as usability problems, the prototype was evaluated in the following way:

- Explicit focus on the interaction modalities: touch, voice, and pen, which were evaluated in our research lab mock-up home with real users employing the "think aloud" process for usability tasks, and an interview;
- Focus on general use of the system, evaluated in a laboratory testing with real users (couples) employing the "co-discovery" process, usability tasks, and an interview.

The basis of these tests was the user tasks and scenarios created from everyday tasks, as elicited from users during the home studies. Any problems uncovered were used to create recommendations for correcting or enhancing the interface and its functionality.

We undertook testing with the users in the interaction laboratory at FTW. We expected the investigation to be explicitly focused on the interaction modalities and assumed a motivated user. We carried out six laboratory test sessions, with eight users. We believe that this number of subjects was sufficient to uncover all the major usability problems, as do other researchers (Dix, Finlay, Abowd, & Beale, 1998; Nielsen, 1993). The users were aged 65 to 80 (average age 72); their gender, previous professional status, and technical expertise were balanced, meaning we tried to include people with a range of skills and an even split of male/female. The first four users carried out a semi-structured set of tasks (Table 3) reflecting the scenarios of everyday use situations and employing the procedure of "think aloud," followed by an interview. *Think aloud* is a process used during evaluations in which the

Table 3. Usability Tasks and the Time Allocated to Perform the Tasks.

Usability Task 1: Start the system on the TV.	3 min
Usability Task 2: Explore the elements of the system.	7 min
Usability Task 3: Send the robot to check whether the cooker in the kitchen is on.	3 min
Usability Task 4: Listen for a response from the robot and act upon it.	3 min
Usability Task 5: Send a verbal command to the robot (e.g., go to the living room).	3 min
Usability Task 6: Change the household heating temperature by using the PDA.	3 min
Usability Task 7: Shut down the system on the TV.	2 min

users are encouraged to talk to the evaluator and discuss freely the problems they are having with the system. By using this technique the users see themselves as collaborators in the evaluation and not simply as experimental subjects. This also allows the evaluator to ask the users questions. According to Dix (1998), this form of evaluation has two advantages: the user is encouraged to criticize the system, and the evaluator can clarify points of confusion at the time they occur and so maximize the effectiveness of the approach for identifying problem areas.

The next four users comprised two couples, and we therefore felt that it was appropriate to use a slightly different methodology. We used the co-discovery procedure, followed by the usability tasks, and then an interview. The primary difference between the co-discovery method and that of the thinking aloud method is that the *co-discovery test* is carried out with the participation of two test persons, who explore the technology on their own without a test leader present. The test persons are supposed to know each other well and explore the technology in an unstructured and cooperative manner. We felt that this was an appropriate methodology for couples and would further provide us with a degree of ecological validity in that some of the households we were concerned with could have two adults who could be expected to explore a new device jointly. An evaluator observed the co-discovery test users' exploration of the technology and completion of the usability tasks.

All the sessions with users were videotaped. We undertook a further analysis of the data and the videotapes with three usability experts (one who had 5+ years experience and the other two who each had on average 2.5 years experience). One expert was working on the project, the second worked for the research center but on different projects, and the final expert was from outside the research center's staff.

Results from the Prototype Evaluation

The analysis of the overall evaluation of the prototype was expected to uncover usability advantages as well as usability problems. These were then expressed in recommendations for correction of detected problems or to enhance the design of the user interaction or interface.

Due to technical problems in one test, the data of seven subjects was considered for analysis. It should be pointed out that the testing and the user experience suffered from the immaturity and the early development stage of the prototype provided at the time of testing. One of the most striking problems in this regard was the long latency of system reactions to switching or selecting options on the different devices. Other problems relating to prototype immaturity were missing functionalities (audio features, settings) or insufficient content quality and quantity (e.g., maps and help instructions).

Results from the co-discovery testing

In the co-discovery part of the evaluation, the couples were particularly inventive in their requests to the robot and sent it all around the lab, trying to get it to go through doors and around objects. They were found to do this even when they did not have a clear idea about what the system did or how to complete a task. Three of the four users thought that they would like to use such a system in their homes.

These test participants found the concept itself quite valuable. Users emphasized positively that the system would support them in their daily lives. However, the user experience suffered from the quality of the system prototype.

There were significant problems in the conceptual and graphic design, which need to be addressed in further development. The main navigation bar was very irritating for the users. Also some of the icons turned out to be difficult to recognize and their aesthetic appeal could be increased. It often turned out that the users did not intuitively understand the meaning or function of certain system parts (e.g., the exact difference between "Applications" and "Items"). Another general problem was the semitransparent mapping of the commands to the remote control buttons. Several severe usability problems were observed during the test and were also mentioned by all participants in the interview. In the next section, the results are summarized for each usability task. The findings reported are from both groups.

Results from the Usability Tasks

Task 1: Start the system on the TV.

Only two test users immediately found the correct button to start the system without any assistance. The remaining users looked in vain for the correct button. Most users thought that the on/off button of the remote control would turn the system on or off. The test facilitator asked the test users which additional buttons they thought may also possibly turn the system on or off. The users suggested the menu button, some numbers from the number block, and the channel buttons. The participants who were engaged in the co-discovery spent a longer time than those users undertaking the tasks individually to find the correct button before asking for help. After receiving help all of the test users could start the application.

Task 2: Explore the elements of the system.

- PDA: When asked about what they thought they could do with the PDA, most test users correctly understood that they could access the different devices via the PDA and control them. One person supposed that it might be the only way that information could be updated.
- Robot: Almost all participants understood that the robot could be sent around the apartment. Some of them experimented straight away with trying to send it to various rooms via the map on the PDA screen.
- Menu: Behind this function the users expected numerous different things. Apart from issuing commands and updating the system (the most frequent answer), they also thought that they may find other home monitoring applications and the ability to add their own rooms and maps.
- Settings: All test persons understood that under this menu item they could change the settings.
- Navigation: It could be observed, and many test users stated this, that the navigation around the menu system on the TV and on the PDA sometimes confused the users. Therefore, our design did not meet one of our aims, that is that the system should support the users navigation in such a way that the user always knows where they are.

Task 3: Send the robot to check whether the cooker in the kitchen is on.

- All but one test person could accomplish this task without effort or assistance. The majority of the users (5) selected to do this via the TV and a smaller number (2) decide to use the PDA. Nearly all users (6 out of 7) completed the task of sending the robot to the kitchen. During this task, the extreme latency was noticed and criticized by the test persons for the first time.

- Sometimes the command was ignored by the system and even after restarting the whole system this problem remained. Two of the users had to try several times to find out if the cooker was on.

Task 4: Listen for a response from the robot and act upon it.

Finding the "listen" button on the remote control caused the most problems. Two thirds of the users understood the function of switching the audio feature on and off. More than two thirds saw the speaker symbol when turning on the feature. The remaining subjects held the button or they had the function permanently activated. However, when they did get a response they were able to hear it and act upon it.

Task 5: Send a verbal command to the robot.

Although the majority of the test persons fulfilled this task successfully, only half thought that they had fulfilled this task successfully. The reasons for this varying result were that the subjects didn't know whether the robot had received the command, and the users didn't know, due to the latency, whether the robot was actually acting on it.

Task 6: Change the household heating temperature by using the PDA.

Two test users thought that they had not accomplished this task, when in actual fact they had. The lack of feedback here was crucial to the users' satisfaction with the system and their perception of how they had performed. A major problem for the users was the navigation through the menu items. It can be seen therefore that another of our main aims was not met, that of the user receiving relevant and immediately understandable feedback.

Task 7: Shut down the system.

Many subjects looked in vain for the correct button on the remote control to close the system. This was perhaps due to the fact that the button was not the usual on/off button on the remote control but another button. It was also a different button from the "on" button. When asked whether they thought that they had successfully switched off the system, five thought that they had but weren't sure if they had turned off the robot and PDA as well, and two thought that everything including the television was turned off (e.g., PDA, Robot and TV). When asked whether they thought that any of their data or settings had been saved when they switched off the system, the majority of the test persons thought that after switching off the system their settings would be stored.

General Evaluation

In general, the test participants found the concept of the system itself very interesting and the technology attractive, commenting that they found the robot particularly enjoyable to interact with. Users emphasized positively that the system supports different modalities and that the user can choose the different interaction mediators (e.g., television, PDA, robot).

The users found nearly all of the available functions and were able to understand, interact with, and complete the tasks (albeit sometimes after receiving help from the observer) on the various devices. Particularly during the co-discovery sessions, we found that the users spontaneously found additional functions and operations for the devices, and this was found to be supported through the very interaction with the technology. This was not the case with the individual users, who required more help and guidance from the observer.

All the users found that the system provided opportunities for exploration and manipulation, that is, the actions taken were found to be modifiable and/or reversible. The majority of the users said that they preferred to receive feedback from the robot (we think this is perhaps due to its novelty value), as opposed to the television or PDA.

Certain evident problems (latency, design, and navigation) were brought up by all the participants in the interview session. In this way, the interview data helped to underscore what was observed during the sessions. There were significant problems in the navigation design, which would need to be addressed in any further development. Also some of the icons turned out to be difficult to recognize and lacked aesthetic appeal. It was also learned that the users did not intuitively understand the meaning or function of certain system parts.

CONCLUSION

The paper started out by saying that the companies who sponsored our research wanted us to concentrate on more utilitarian concepts for the home. After undertaking background research, we discovered that a more expanded brief was required to ensure the success of our proposed home system. We, therefore, included other issues of importance to those using such products in the home, in particular aesthetics, control, privacy, and fun.

In order to ensure the usability and acceptability of our system, we undertook some requirements gathering from home studies that involved three households in central Scotland. The focus of this study was to elicit ideas from the senior participants about what type of home system they would like. We found that including the seniors in our requirements gathering led to more fun and unusual suggestions. For example, we had anticipated that a mobile device might not be welcomed by senior citizens, but their design sketches (see Figures 1 & 2) showed us that they would be happy to use a mobile device if there was a need for it. The seniors also mentioned that they did not want the monitoring system to be too utilitarian or stigmatizing.

We tried to avoid the pitfalls of patronizing the elderly and treating them as a homogenous group by providing technologies that would meet the specific needs of this diverse group. The findings from our home study, supported by earlier research, led us to include a mobile device and the Internet in our system, thus allowing the system to be accessed and controlled remotely. The television was chosen as one of the interaction devices because it is already in most people's homes and therefore meets the stated wish for unobtrusiveness and non-stigmatization. Our home studies also revealed that the television was a highly esteemed artifact among the elderly users.

A small robot was included in the system as an enjoyable and lightweight monitoring device. Earlier research (Friedman, Kahn, & Hagman, 2003) had indicated that elderly people felt comfortable using and also ignoring robots and similar devices in their homes. A robot was thought to be a useful solution as well, because it can be picked up easily and put out of view, thus not affecting the fixtures and fittings and helping the elderly person not feel stigmatized.

Finally control of the system was designed to rest with the householder or whomever he/she decides to give access. This, too, fulfilled the seniors' desire that they not be treated in a condescending way.

There were some concerns about whether our elderly participants would adopt such a new innovation and thus we undertook a user evaluation. However, we firmly believed, like Dunphy and Herbig (1995), that the elderly will be more willing to adopt a new technology if it meets their needs and the benefits in using it are effectively communicated.

In the evaluation part of our study, we found that the co-discovery method worked best and elicited most of the insights from the usability testing. Also, the users in these sessions seemed more relaxed about criticizing the system and trying out different functionalities. We would, therefore recommend this method to any other researchers who are undertaking research in this area. The users said that they enjoyed using the system and the three experts who reviewed the videotapes of the user interactions with the system agreed that the users looked happy and relaxed; they even went as far as to say that the users looked like they were having fun.

The overall evaluation found many usability and functional problems with the original prototype, such as navigational errors and problematic icons, which were mainly due to the system's early stage of development. We have since resolved most of these issues and will complete a new version of the design in the near future.

In general, the test participants found the concept of the system interesting and the technology used attractive. The robot was viewed by the users as being the most engaging part of the system and this was the part of the system that they chose as the most attractive to interact with. Of course we are aware that this could be due to the novelty value of such a device and that a home-based study may show that this interest does not continue over a lengthier period of time.

In conclusion we found that it is not always necessary to design solutions that are primarily utilitarian in nature for home monitoring. It can also be useful to think of using devices that have been developed for fun and amusement and put them to a more utilitarian use, such as the robot. There are and will be in the future an increasing number of different types of lightweight mobile monitoring systems for the home. Therefore, it is crucial that the community for whom these artifacts are built contribute to the discussion of what assistive technologies are appropriate and desired in the home. With the intention of addressing this issue, we presented our prototype of a multi-agent, lightweight, user-controlled network for the home for supporting the elderly.

ENDNOTES

1. Aging in place is a concept that favors giving older persons the opportunity to remain in their own homes rather than be cared for in an institutional setting. The improvement of housing conditions and associated services that enhance the mobility/accessibility of the elderly and which contribute to improving their physical/mental condition is critical to sustaining people's level of activity necessary for maintaining independence and quality of life.
2. Low level-monitoring is a system that provides information such as whether the lights are on or off and what the temperature is in certain rooms.
3. See Lejos (n.d.). Lejos–Java for the RCX. Retrieved February 10, 2006 from http://www.iau.dtu.dk/~lego/lego3/rcxcomm/

4. Having a transparent tool is a precondition for having a conscious focus on the goal of an ongoing task, meaning the user is acting without thinking about the operation.

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All correspondence should be addressed to:
Dr. Lynne Baillie
FTW
Donau-City-Strasse,
Vienna 1020, Austria
baillie@ftw.at