Sensor Monitoring in the Home: Giving Voice to Elderly People

Marije Kanis, Saskia Robben, Judith Hagen, Anne Bimmerman, Natasja Wagelaar & Ben Kröse

Amsterdam University of Applied Sciences

Amsterdam, The Netherlands

m.kanis@hva.nl

Abstract—**This paper describes the approach used to identify elderly people's needs and attitudes towards applying ambient sensor systems for monitoring daily activities in the home. As elderly are typically unfamiliar with such ambient technology, interactive tools for explicating sensor monitoring –an interactive dollhouse and iPad applications for displaying live monitored sensor activity data– were developed and used for this study. Furthermore, four studies conducted by occupational therapists with more than 60 elderly participants –including questionnaires (n=41), interviews (n=6), user sessions (n=14) and field studies (n=2)– were conducted. The experiences from these studies suggest that this approach helped to democratically engage the elderly as end-user and identify acceptance issues.**

Elderly-centred design; Ambient Assisted Living; Occupational therapists; Sensor monitoring; Sensor displays

I. INTRODUCTION

With the growing awareness of the importance of engaging users in the design of technology, there is an increasing recognition that older people should also be involved in the design and evaluation of technology that could assist them in living their life longer independently. However, engaging elderly by researchers and technologists is not typically a straightforward process. For example, the technical design and developing party may have potential biases towards using particular technology, have difficulties explaining their technical ideas and not be familiar with dealing with potential cognitive and physical limitations of elderly users. Such issues can hinder the needed shared understanding of the parties involved. To address this, this paper describes a different approach that includes studies conducted by occupational therapists and visual displays to help older people democratically identify and describe the acceptance issues that they encounter with monitoring technology.

A. Residential Monitoring

The demographic change of aging populations in developed countries has motivated a large body of research to specifically focus on technologies that are targeted at elderly people. In this vein, the field of Ambient Assisted Living (AAL) focuses on ambient technologies to support and help elderly live longer independently. Ambient sensor monitoring is particularly being explored for this purpose. Typically, it is focused on the residential monitoring of elderly Activities of Daily Living (ADL); a set of activities used by physicians to benchmark physical and cognitive decline. The use of sensor monitoring technology in independent living settings is promising, as it could support earlier detection of changes in daily activity patterns, like reduced activity in an elder's home and so alert health care providers to intervene earlier. However, according to a literature review [1], more work focusing on understanding the needs from the perspective of the elderly is needed. Particularly, technology that removes control from the elderly user can undermine the purpose by not letting them function independently [2]. For example, in the case of ambient sensor technology, independence is not achieved by, and may even be undermined by, providing feedback about an individual's status to someone else, such as in a sensor report about functioning sent to caregivers instead of reporting to the elderly individual.

B. Occupational Therapists for Engaging Older Adults

Mitzner and Rogers [3] state that by involving older adults in the design process, technologies can be developed that are more useful and usable for older adults and may, therefore, increase their acceptance rates and contribute to successful aging. However, democratic inclusion of older adults has been recognized as challenging and needing a different approach [4]. Involving occupational therapists in such processes could help to increase common understanding between the elderly and other parties. Although collaborations between technologists, and even practitioners in the field of Human Computer Interaction (HCI) and occupational therapists are not standard practice, these latter groups both share the basis that the needs of a human being are central in their activities. Occupational therapy is generally applied to aid individuals in recovering and regaining as much independence as possible and so is also used to address problems that develop as a result of getting older. An occupational therapist can assess one's ability to carry out everyday tasks, such as washing, cooking or dressing oneself, and offer advice or techniques to help with these activities. Therefore, occupational therapists can typically help to democratically assess acceptance issues when regarding a sensor system for monitoring elderly people's daily activities.

C. Displaying Ambient Concepts for Engaging Older Adults

Another problem with exploring ambient design concepts with elderly is adequately explaining the scope of the technologies involved. Researchers [5] found that showing simple mappings between sensors and display in demonstration applications in an ambient-technology augmented kitchen

could greatly improve users' understanding of the potential functionality. In this line, this study explores the involvement of occupational therapists, and also the use of interactive visual tools to help to articulate and understand ambient monitoring technology from an elderly point of view.

Several projects attempt to help elders maintain their independence. For example, the CareNet Display [6] is used for reassuring the care network around an elder in the home. However, directly targeting elderly people as end-users of ambient system displays in the home is not standard practice. Research that also targeted the elderly [7] found that elder study participants had more difficulties with interpreting and interacting with a sensor activity display. Such work demonstrates the need for studies and displays that address the elderly as end-user in ways that they can understand.

II. STUDY APPROACH

Different approaches were taken to assess the needs and attitudes of elderly people with regards to monitoring their daily activities with sensors in their homes. The initial Living Lab context concerning this study is on-going work, involving the set-up of the needed infrastructure to conduct the studies, including the making of the necessarily social, organizational and technical connections. Then, the primary stage of this particular study comprised the development of several interactive visual tools for explaining ambient monitoring and sensor data activity to elderly. In the secondary stage, these tools were used in several studies by occupational therapists to democratically assess issues with elderly that concerned the use of sensor monitoring. This study lasted for more than one year.

A. Living Labs for Health Innovation

A large part of this work was carried out in a Living Lab setting, an environment and infrastructure where real users can be exposed to applications in their daily life so to aid designers and developers improve their products. The Living Lab concept was originally coined by Mitchell at MIT, as an approach for sensing, prototyping, validating and refining complex solutions in evolving real life contexts. In The Netherlands, several Living Lab locations have been set-up as part of Health-lab, a program that focuses on innovative solutions for enabling people to live longer independently. In this program, people from diverse care institutions, research labs, educational institutes and companies closely work together with end-users to co-create (technical) solutions. The program's first Living Lab for health innovation was Nursing home Naarderheem, and
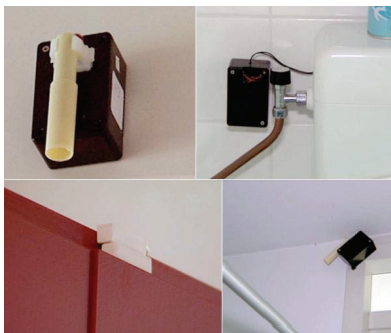
originally set in motion in 2006. The current Living Lab setting involves apartments in different locations that were eventually equipped as AAL environments in which sensor-monitoring systems have been installed (see Fig 1).

B. Tools to Exemplify Ambient Monitoring

For democratically engaging the elderly as end-user, interactive tools were developed to demonstrate and explain the workings of the proposed monitoring system and the sensor activity output (see Fig. 2). Namely, an interactive dollhouse and iPad applications displaying live monitored sensor activity data were developed that target the elderly user.

Figure 2. Interactive tools for exemplifying sensor monitoring: iPad application and first version of the interactive dollhouse (with visible sensors)

1) Interactive dollhouse

Sensor-equipped dollhouses were developed for increasing people's understanding of the existence and desired workings of ambient monitoring technology in the home by demonstrating its potential (see also [8]). The dollhouses, scale models of the different sensor-equipped homes, were developed and used to engage elderly users in residential monitoring. The scale models have been equipped with simple sensors that are able to track movement and so simulate the actual monitoring environment. The models were used as an elderly-centered research and design method in different settings for increasing understanding of the desired workings of ambient monitoring in the home.

Figure 3. The interactive dollhouse (latest version with hidden, embedded sensor technology and direct display)
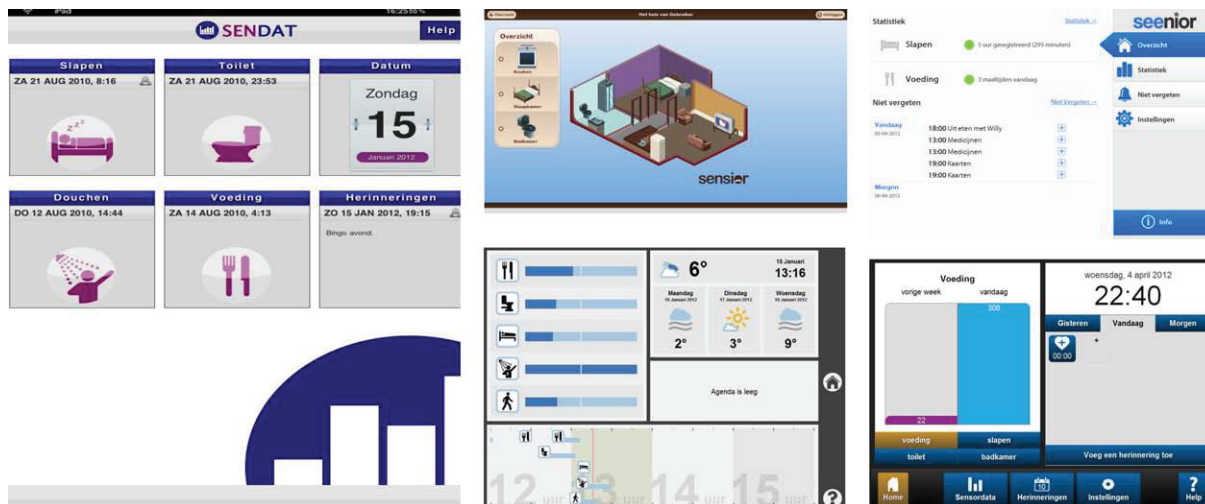

Figure 1. Sensors installed in the homes of the elderly participants

Figure 4. Screenshots of the five different developed elderly-centred applications for visualizing sensor activity

2) Elderly-centered apps for demonstrating sensor activity

As part of a third-year student assignment, 25 students (in groups of five) from the university's program on Communication and Multimedia Design (CMD) were given the assignment to develop an iPad application that displays ambient sensor activity data in relevant and meaningful ways to senior users. In the design of these products, elderly (n=34) were actively engaged in the design of these products (and recruited by the students themselves), in order to contribute to the success and acceptance of such technology. This led to five elderly-centered apps (see Fig. 4), which were all able to show the sensor activity data, but differed in (additional) features (such as a weather forecast) and user interface. Another student from a Technical Informatics course got then involved in linking the developed apps with the actual ambient monitoring systems in the Living Lab environment in Naarderheem. Graduate students in occupational therapy continued with more in-depth studies concerning elder's attitudes with regards to residential monitoring and also evaluated the resulting five apps with elderly users.

III. STUDIES BY OCCUPATIONAL THERAPISTS

Four studies were conducted by occupational therapists under supervision of experts in HCI and sensor monitoring for assessing elderly people's attitudes and needs with regards to sensor monitoring systems. These were the following:

1) Questionnaires for assessing overall views on sensor monitoring, data sharing needs and developed apps:
A questionnaire was given to elderly living in residential homes in the Dutch regions West-Friesland and Lelystad to gather views on applying sensor monitoring and the developed apps. The recruited respondents were unfamiliar with residential monitoring at first instance. The questionnaire explained the concept of sensor monitoring with a photo scenario and screenshots for each of the five apps were shown.

2) Interviews for exploring attitudes towards applying sensor monitoring, using the interactive dollhouse:
To gain a deeper understanding of applying sensor monitoring, semi-structured interviews were held in the homes of the elderly participants who were recruited from the first study. Similar subjects as in the questionnaire were discussed, but this time the interactive dollhouse with sensors was used for better explaining and engaging the participants in the proposed monitoring technology.

3) User study sessions to evaluate the developed apps:
For determining the use and usability of the five apps, four user group sessions (including 3-4 participants in each session) were conducted. During each session, all the five apps were actively tried, discussed, and compared. The sessions started with an initial introduction led by the occupational therapists, then participants were subsequently asked to "think aloud" when progressing through the given usage tasks. After using all the apps, they had to pick their favorite.

4) Pilot field study for testing the use of the most favored app in real settings:
For testing the use and experience with the app in a real (living lab) situation in Naarderheem, two elders that have sensors installed in their homes used the most favored app for one week. Thus, the app was connected to their own sensor network so they could view their own sensor activity data. After that week, a semi-structured interview was held to gain insights into their experience.

IV. STUDY FINDINGS

The results of the studies –(1) questionnaire; (2) interviews; (3) user study; and (4) field study– present multifaceted insights in acceptance aspects of ambient sensor monitoring.

1) The questionnaire:
This study led to 41 respondents between 65 and 89 years of age. The occupational therapists selected and recruited the participants, obtained the necessary consent, and offered door-to-door assistance with filling in the questionnaire. Still, not all of the participants were able to answer every single question of the extensive questionnaire. Interestingly, the majority of the questionnaire respondents expressed not to want to use sensor monitoring at this moment in time (92%, n=38). Also, before the explanation provided by

the questionnaire and therapists, the majority of the participants indicated to not understand the concept of sensor monitoring (65%, *n*=40). Interestingly, from the eight participants who had indicated to understand the concept of sensor monitoring, two participants still thought it concerned the use of cameras, something that is not the case. When participants were positive about sharing the monitored activity data with others, and were asked to differentiate between several parties –home care, family, friends, neighbors or technical experts– home care ranked first and neighbors came out as least favorite to share their data with.

2) Semi-structured interviews: The interviews were held in the homes of six elders (and four of their partners) which had a mean age of 77 years (*SD*=7,3). The results show that the majority of participants (83%) were positive with regards to applying sensor monitoring now or in the future. This more positive outcome than in the first study could be because a more explanatory method was used. According to the participants, the dollhouse, which was used during the interviews, gave more clarity into sensor monitoring. During the interviews, more profound arguments were brought up whether to use sensor monitoring. Positive arguments were an improved sense of security and independence. As one participant noted: "It is reassuring to know that there is someone watching over you". Negative brought up arguments were the potential costs involved and breach of privacy.

3) User study: From the fourteen user study participants, one participant was not able to finish the session, because of fatigue. Such physical limitations are common when doing studies with elderly people [9]. Also holding the iPad or touch interactions with the device seemed strenuous for some. In using the tablet interface, the participants revealed a lot of variations in skills. Findings, that also Van der Geest [9] found when conducting Internet user studies with elders. The participants expressed a preference for simple applications with clear wordings and a minimal amount of screens, as in the one chosen most favorite, shown at the bottom of the middle in Fig. 4. For the final field study, the most favored working app was adjusted for usage in a real situation.

4) Field study: For this final study, a small sample was recruited (*n*=2), because of the difficulty of obtaining willing elderly participants living in homes with sensor networks already installed. The two participants, who used the sensor activity app in combination with their sensor network in their homes, both checked the app several times a day, suggesting an interest in their own data. Participants indicated to be mostly interested in seeing their data over a longer period of time and so witness potential decline. Moreover, the participants indicated to appreciate to be able to have their say over their own sensor data.

V. DISCUSSION

Further investigations with a larger sample size to study sensor technology usage with elders in real settings are recommended. This, however, comes with many technical, social and practical challenges. For example, getting to the stage in which elderly people are willing to have sensor networks installed in their homes is quite an undertaking. And when these are in place, elderly participants frequently become ill, may pull out of study or other unexpected things can happen, such as participants switching off systems to save electricity. Furthermore, as this research and others [9] found, older age often coincides with (more) physical and cognitive limitations, such as becoming hard of hearing, or having difficulty memorizing new material making it harder to directly include elderly in technology usage, study and development. For this purpose, the collaboration with occupational therapists during the study was beneficial in many ways, such as in the participant recruitment process. Also in the interactions and dealings with participants, and carrying out the studies with the elderly without a technology bias, this was very valuable. Although interdisciplinary studies, particular within the field of pervasive health are not uncommon, further exploring the relationship between occupational therapists, technologists and HCI researchers deserves attention. The studies conducted by occupational therapists offered an insight into the priorities and perspectives of the individuals, and particularly the elderly participants involved. The studies showed that engaging, explaining and letting the elders experience monitoring by using visual tools such as dollhouses and the apps visualizing sensor activity helped the elderly in a better and more democratic discussion of the technology. This can be considered necessary, as the study results indicate that the majority of the study participants were not positive and did not understand or want to engage in the sensor monitoring of daily activities at first instance.

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