

# Ambient Assisted Living: Benefits and Barriers From a User-Centered Perspective

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**Abstract**—Older adults have a growing desire to remain independent and age in their own home environment. Policy makers support this wish, as the quality and quantity of institutional care cannot be guaranteed with the present health care budget. Ambient Assisted Living (AAL) technologies can meet the interests of both parties, by facilitating healthy and active aging in the home environment. However, those technologies are still in their infancy and the likelihood of their adoption remains uncertain. By conducting a literature study and a user-requirement study for a conceptual AAL application called SONOPA (Social Networks for Older Adults to Promote an Active Life), benefits and barriers to the adoption of AAL technologies, as perceived by the elderly user, were identified. The user-requirement study consisted of focus groups and interviews with older adults and elder care professionals, conducted in the UK, France and Belgium. Together, the literature study and the user-requirement study led to several design guidelines which direct the future development process of SONOPA and related AAL applications.

*Keywords*-AAL; elderly; benefits; barriers; design.

## I. INTRODUCTION

Worldwide the proportion of elderly people is increasing. With 18.2% of the population being 65 years or older in 2013, Europe has one of the highest shares of elderly people in the world [1]. It is expected that this proportion will rise to almost 30% by 2050 [2]. This goes along with a sharp increase in the old-age dependency ratio, meaning that the number of potential recipients of health and pension funds rises (65 years and older), while the number of potential providers of funds belonging to the working age population (15-64 years), continues to decline [2][3]. While global aging can be considered as a great accomplishment of today's socially and technologically advanced culture, it creates immense challenges for governments in terms of healthcare regulations, pension schemes and state budgets [2].

To meet these challenges the concept of AAL was introduced. AAL is an umbrella term for innovative Information and Communication Technology (ICT) based products, services and systems which support healthy and active aging at home, the community and at work [4]. By promoting a healthy and autonomous lifestyle, AAL technologies meet both the elderly people's desire to remain independent and age in place and the demand for controlling healthcare cost [5][6].

Despite the fact that AAL technologies offer a promising perspective on successful aging, the likelihood of adoption of those technologies remains uncertain [7]. Usability problems [6][8], the lack of perceived benefits [5][7][9] and technology self-efficacy [7][10] can form, among other factors, severe barriers to technology adoption among elderly people. In our view, this heightens the need for a user-centered approach when designing AAL technologies, to access the wishes and needs of the intended user and identify potential benefits and barriers at an early stage of development.

The presented work is part of the SONOPA project [11] which is carried out in the framework of the AAL Joint Programme. The aim of the SONOPA project is to employ a set of available ICTs for stimulating and supporting activities at home. Various sensors and behavior modelling techniques will be used to generate a personal activity profile of the elderly user and track variations in the daily activities over time. When the user's activity level is low, the system will provide a recommendation, suggesting individual activities or social interactions with peers. SONOPA seeks to empower elderly people to stay active, independent and socially involved in their home environment, so to maintain their psychological and physical well-being. The work described in this paper was carried out in the first year of the project to access the perceptions and needs of the user at an early stage of development. Results are used for the further development of the SONOPA technology over the remaining two years of the project life span.

In this paper, several design guidelines for AAL technologies are identified. Findings are based on both insights from a literature study and a user-requirement study conducted as part of the SONOPA project. Section II and Section III provide an overview of the literature study with regard to the perceived benefits and perceived barriers of assisted living technologies. The user-requirement study points out to what degree benefits and barriers could be supported by our user data. Results are described in Section IV. Together, these insights led to several design guidelines which are directive for the future development process of SONOPA and related AAL applications. These guidelines are described in Section V. Section VI provides a general conclusion and implications for the future development process of the SONOPA system and related AAL technologies.

II. PERCEIVED BENEFITS

To get an insight in the perceived benefits and barriers of AAL technologies, relevant literature about AAL and related technology applications designed for the purpose of healthy and active aging in place was reviewed. We searched several scientific databases (Scopus, Web of Science, Google Scholar) with keywords such as ‘older adult’, ‘assistive technology’, ‘(ambient) assisted living’, ‘robots’ ‘monitoring’, ‘independent’, ‘adoption’, ‘use’ or synonyms of these words. After initial screening of titles and abstracts, we included sixteen articles applying the following criteria :

- Peer –reviewed
- English language
- Published between 1999 - 2014
- Systematic review, qualitative study, quantitative study or mixed method approach
- Research focusing on the adoption and use of technology applications designed for healthy and active aging

The selected papers studied different AAL applications such as in-home sensor technologies, social network applications, domestic robots or the more general concept of technologies for aging in place (see Table 1).

TABLE I. OVERVIEW SELECTED PAPERS

Ref.	Name of Journal	Technology Application
5	International Journal of Medical Informatics	in-home sensor/monitoring technology
6	Informatics for Health and Social Care	technologies for aging in place
7	International Journal of Medical Informatics	consumer health ICT
12	Gerontechnology	in-home sensor/monitoring technology
13	Journal of Housing for the Elderly	technologies for aging in place
14	International Journal of Medical Informatics	technologies for aging in place
15	International Journal of Medical Informatics	in-home sensor/monitoring technology
16	Journal of Applied Gerontology	in-home sensor/monitoring technology
17	Proc. of the SIGCHI conference on Human factors in computing systems	in-home sensor/monitoring technology
18	International Journal of Social Robotics	domestic robots
19	Social Science & Medicine	technologies for aging in place
23	HCI and Usability for e-Inclusion	social network application
29	Journal of the American Medical Informatics Association	consumer health ICT
30	International Journal of Social Robotics	assistive social robot
31	Disability and Rehabilitation	emergency alert, door monitor, stove controle
32	Journal of Telemedicine and Telecare Telecare	in-home sensor/monitoring technology

Several studies tested the assistive device (mostly prototypes) in the field. We extracted the perceived benefits and barriers of those technologies from the selected papers and grouped them into categories. Consequently, six benefit and eight barrier categories could be identified. The benefits are discussed below. The barriers are discussed in Section III.

A. Independent Living and Aging in Place

Independent living and aging in place are perceived as essential benefits of assisted living technologies [5][12]-[16]. Steel, Lo, Secombe, and Wong [5] reported, that independence is of utmost importance to elderly people and technology which can facilitate autonomous living, is perceived as useful. This is contributed by the fact that many elderly people have a negative view on nursing homes and regard institutionalization as a last resort [5][15]. The desire for independence is so strong, that it often supersedes other concerns, such as privacy and intrusiveness [16][17].

B. Health and Safety

Health and safety are prerequisites for aging in place [15] and perceived as important benefits of assisted living technologies. Hence, responding to emergencies [5][6][12][13][15][16][18][19]; detecting and preventing falls [5][6][12][13][15][16][19]; and monitoring medical parameters [5][6][12][16][18] are regarded as key features of those technologies. Other valued features include property security [6][18] and detecting safety hazards, e.g., fire or unlocked doors [6][15][18]. Automatic and around-the-clock monitoring is viewed as a major advantage of sensor-based assistive living technologies in comparison with existing solutions, such as an emergency button or a human caregiver [5][15].

C. Social Involvement

Another benefit of assisted living technologies concerns the improvement of the user’s social involvement. Social connectedness has been described as a key element of a good quality of life [20][21] and successful aging [22]. In the ‘Building Bridges’ project [23], elderly people met fellow seniors via online calls and chat to discuss a broadcast they had commonly listened to. Participants stated that they were very keen to arrange real-life meetings and get to know their conversations partners. The field trial of the ‘Digital Family Portrait’ project, revealed that the female participant felt less lonely, knowing a family member was watching over her with the help of technology [17].

D. Support with the Activities of Daily Living (ADLs)

With older age physical, cognitive and sensory impairments such as muscle stiffness, memory decline and poor vision increase [24]-[27]. Assisted living technologies can help elderly people to compensate for these deficits and help them with their ADLs. Indeed, Smarr et al. [18] found that elderly people would value the assistance of domestic robots in helping them with chores such as cleaning, fetching objects or reminders, e.g., taking their medicine. With those

tasks robotic assistance is even preferred over human assistance. Similarly, Demiris et al. [6] found that older adults identify assistance with impairments and a reminder function as potential advantages of assisted living technologies.

#### E. Support Care Network

Both, informal caregivers and the elderly people themselves perceive assisted living technologies as good tools to support the care network because they provide some piece of mind and reduce the overall burden of family caregivers [14]-[17]. With the help of in-home monitoring, caregivers can gain a better understanding of the elderly person's well-being, and it allows them to detect functional and cognitive decline at an early stage [16][17].

#### F. Education and Leisure

Opposed to common stereotypes, a good proportion of elderly people are still capable of learning new things and is still fairly active and productive [28]. In the 'Building Bridges' Project [23], participants were positive about the educational element of the tested device. Several of the participants acknowledged that modern technologies could help them to develop and share their personal interest with others.

### III. PERCEIVED BARRIERS

Besides benefits, eight perceived barriers which could interfere with the successful adoption of AAL technologies were extracted from the literature study. The insights on those barriers are discussed below.

#### A. Perceived Need and Perceived Usefulness

The subjective need and the perceived usefulness of a new technology are essential for elderly people to adopt it [7][9][14][29]-[31]. Consequently, the lack of subjective need and perceived benefits forms a major barrier to accepting assisted living technologies [5][14][16][19]. The subjective need for assisted living seems to be influenced by the elderly person's perceived well-being in terms of health, activity and social involvement. Steele et al. [5] found that elderly persons with good social ties were less likely to feel the need for such a technology. Greenhalgh et al. [19] discovered that their participants saw no value in assistive technologies if they had never needed to use it before. Zimmer and Chappell [31] indicated that the subjective health status stimulated the felt need for a technology which can improve the independence. However, many elderly people struggle to imagine future deterioration where they might benefit from features such as monitoring [16]. This is confirmed by Peek et al. [14] who concluded that many elderly people talk about a hypothetical older person who could benefit from assisted living technology rather than themselves. The use of existing technologies, such as an emergency button and the help of family members or a spouse can also reduce the perceived need for assisted living technologies [14]. This is contributed by the fact that many elderly people do not fully understand the additional benefits assisted living technologies can provide [5][19]. While the

perceived benefits are more abstract, the concerns related to those technologies are very specific [14].

#### B. Privacy, Obtrusiveness and Control

Concerns about privacy, security and possible intrusion are perceived as important barriers to the adoption of assisted living technologies [6][12][14][19][23]. Elderly people are worried that their personal information can get in the wrong hands and be misused. Some are reluctant to the monitoring aspect of assisted living technologies, as it feels like surveillance to them. Especially the use of cameras, is strongly rejected [6][12]. In contrast, some studies find that privacy is just a minor concern to their elderly participants [5][15][16]. They regard some loss of their privacy as a valid trade-off for their safety, independence and health. Another reason could be the lack of awareness of potential security risks.

The perceived obtrusiveness of assisted living technologies is another concern which is voiced by the elderly target group [5][14][15][19][23]. They are worried that technologies are too visible in their home environment, and could interfere with their normal routine. Indeed, some participants in the study by Van Hoof, Kort, Rutten and Duijnsteet [15] complained about visible cables, annoying sounds and interference with other devices, such as the TV.

Finally, the level of user control is a matter of concern to the elderly user. Most elderly people want to have some level of control about the technology, e.g., turn it off manually. Consequently, the lack of user control is perceived as a barrier [5][14][16]. On the other hand, some elderly people argue that a monitoring system cannot assure safety, unless it is switched on all the time. Emergencies could happen when the system is switched off or when users forget to switch it back on [5]. A low level of user-control would also be more suitable for people who are not very confident in interacting with technologies [6].

#### C. Lack of experience, technology anxiety and self efficacy

Several elderly people are apprehensive towards technology and worry about their abilities concerning technology use [5]-[7][14][15][23][29]. They perceive technology to be very complex and inaccessible for elderly people who miss the necessary skills and experience. Ease of use and making mistakes when interacting with the technology, are major concerns. However, some of them are willing to undertake training and believe that this knowledge could make the interaction with the technology easier [5].

#### D. Social Stigma

A social stigma is also identified as a potential barrier to the acceptance of assisted living technologies [5][6][14][19]. Many elderly people are hesitant to use technologies which could stigmatize them as frail or needing assistance. Some admit to be ashamed of wearing existing solutions, such as a panic button and wanted sensor systems to be as discreet and unobtrusive as possible. The concern about the social stigmatization seemed to be especially prevalent for female seniors [5].

### E. Reliability

Many elderly people worry about the reliability of assisted living technologies and question the accuracy and ability of those technologies in ensuring the health and safety of the user, compared to a human caregiver [5][6][14][15]. Indeed, several participants in an earlier study reported false emergency alarms when using an assisted living technology application [15].

### F. Lack of Human Interaction

The lack of human interaction is also a matter of concern to the elderly target group. They think that assisted living technologies cannot and should not replace human assistance and human interaction [5][6][32]. Indeed, Smarr et al. [18] revealed that while robot assistance is accepted for certain tasks, human assistance is preferred for personal care tasks (e.g., wash hair), leisure activities (e.g., playing games) and most health related tasks (decide which medication to take). Van Hoof et al. [15] found that the video-call feature of their assisted living application was hardly used and did not help to improve the user's social connectedness or loneliness. Steele et al. [5] found that the elderly participants rejected the suggestion to incorporate social aspects in an in-home monitoring application as they did not believe this could impact their social life.

### G. Cost

Another barrier concerns the cost of assisted living technologies [5][6][14][32]. Several elderly people have stated that, due to their limited income, such systems would either not be affordable to them, or they would not be willing to spend a lot of money on such technologies. Elderly people also mentioned that cost should be subsidized by the government.

### H. Health Concerns

Finally, the last barrier regards health concerns. Several elderly people worry that electromagnetic radiation caused by wireless sensors could cause health problems [5][14].

## IV. USER-REQUIREMENT STUDY

To evaluate the perceived benefits and barriers identified from the literature study in the context of the SONOPA technology, a user-requirement study with older adults and elder care professionals was conducted.

### A. Method

Three focus groups (UK:  $n = 8$ ; FR:  $n = 5$ ; BE:  $n = 9$ ) and semi-structured interviews ( $n = 21$ ) were conducted in the UK, France and Belgium. In total, 28 older adults aged between 55 and 86 ( $M = 71.36$ ,  $SD = 9.45$ ) participated in the study. Six older adults participated in both focus-groups and in-depth interviews. Of all participants, twelve were male and sixteen were female. Nine participants lived on their own, while the other participants lived with a partner, family members or a friend. The older adults lived independently and without the regular help of a formal or an informal caregiver. A few seniors depended on their family members or external help for certain chores such as cleaning,

transport, grocery shopping or gardening. The physical well-being ranged from "perfectly alright" to "I don't feel myself at all at the moment". However, the majority felt fairly healthy. Overall, participants also felt fairly active, ranking their own activity level at an average of 7.06 ( $SD = 2.07$ ) on a 10-point scale. Moreover, the majority of the older adults felt socially involved, ranking their own level of social involvement at an average of 7.32 ( $SD = 1.59$ ) on a 10-point scale.

The Belgium focus group was conducted with four male and five female elder care professionals. The professionals were aged between 36 and 61 years ( $M = 46.50$ ,  $SD = 9.89$ ) and had an average of  $M = 14.44$  years of work experience in the care sector ( $SD = 6.32$ ).

A video was used to visualize two potential user-scenarios of the future SONOPA technology [11]. Subsequent questions targeted the following topics:

- Problems related to ADLs and the level of social involvement
- Opinion about the SONOPA solution
- General level of technical skills and design requirements for technology for elderly

The recorded material was then coded according to the benefits and barriers perceived by the participants.

### B. Perceived Benefits

Almost all of the benefits found in the literature study were supported in the user-requirement study with regard to the future SONOPA technology, with the exception of the benefit 'independent living and aging in place'.

1) *Health and Safety*: Safety was an attribute which was highly valued with regard to the future SONOPA technology. Older adults and elder care professionals both felt that embedded sensors could provide added safety and security by detecting abnormal behavior such as falls or other emergencies, and automatically contact help. Thus, like in previous studies, 'fall-detection' and 'emergency response' were identified as key features. Automation was regarded as the main advantage in comparison with existing solutions: "I have a panic button on my mobile [...]. But as far as I'm concerned it is practically useless. Because if something serious happens it is either going to be on the other side of the room, or in your hand bag, or you're not capable to press the button. So really what you are talking about, is a lot more helpful". Again, this confirms previous findings [5][15]. Another feature which was suggested to be incorporated to the SONOPA system was a reminder for turning off the stove.

2) *Social Involvement*: Social involvement was perceived as an important advantage of the future SONOPA technology. Participants from both groups liked that the technology would allow elderly people to make new friends and strengthen the neighbourhood network: "It's like a social club." They also valued that one could stay in touch with family and other existing contacts. Participants appreciated that contact would be one-on-one and could

lead to real-life interaction. They concluded that SONOPA could prevent social isolation by getting people outside the house, motivate them to participate in social life and therefore give them back a sense in life. By aiding social involvement, SONOPA could simultaneously stimulate the elderly people's activity level: "If you meet someone, you get ready, you clean the house and you get busy with other daily chores. And in this way this kind of technology could contribute to staying active". While this is in line with finding from some researchers [17][23], it contradicts findings from Steele et al. [5] who found that their elderly participants strongly rejected the suggestion to incorporate social aspects in an assisted living technologies. However, one elder care professional argued that particularly these social aspects could be the reason that the more healthy and active elderly people would be interested in SONOPA: "For some people safety would not be such a big problem at first, and if that is all there is, they probably would not get [the technology] installed. But it also includes some social elements which could maybe convince people to get it installed anyway. This way they get familiar with [the technology] [...] and by the time it is needed for safety purposes than there is already a good [activity] profile of this people and that I consider a strength". Mynatt and Rogers [33] also implicated that the more technologies can be incorporated in the homes of fit elderly, the more likely they will be to adopt more advanced assistive technologies when their health declines.

3) *Support with the ADLs*: In line with previous studies [6][18], assistance with chores and reminders (e.g., medicine, important appointments) was much appreciated among older adults and elder care professionals in the context of the future SONOPA technology. A few older adults especially liked that there would be a possibility to get personal advice from peers or family members via video-chat. One of the elderly UK participants even suggested to use SONOPA to recruit help for chores through the network feature: "But imagine if you want to decorate your kitchen and you put it on there, you could have five people come around and you could go shopping and come back and it would all be done". Additionally, elder care professionals and older adults found the automatic door openers which could be incorporated in SONOPA quite helpful in aiding people with mobility problems.

4) *Support Care Network*: The older adults stated that SONOPA could be very valuable to support the care network and provide peace of mind for the relatives. One participant regretted that a similar technology was not available when she was an informal caregiver: "When mom was older I looked after her to be sure she is well. And I think this kind of solution would have been very valuable in that situation". Again, this is line with previous findings [14]-[17].

5) *Education and Leisure*: Some older adults also saw the potential SONOPA social network feature as an opportunity to share common interests and educate themselves. As one elderly participant stated: "I do watercolour painting, I might find somebody who wants to come in with me once a week and sit." Another participant suggested to incorporate online classes or educational videos in the SONOPA system. Wherton and Prendergast [23] had similar findings.

A possible explanation why 'independent living and aging in place' was not explicitly mentioned with regard to SONOPA, is that SONOPA was already presented as a conceptual technology for healthy and independent aging at home. Therefore participants might have felt that this was an obvious advantage and therefore unnecessary to recall. However, various statements made clear that independence is very important to the participants. This, and the fact that it was a major advantage in previous studies lead to the conclusion that 'independent living and aging in place' indeed should be emphasized as a benefit of AAL technologies.

### C. Perceived Barriers

Besides 'health concerns', all barriers identified in the literature study were supported in the user-requirement study with regard to the future SONOPA technology.

1) *Perceived Need and Perceived Usefulness*: Although the majority of the older adults liked the general idea of SONOPA, many felt no need for it in their current situation. They found the concept of SONOPA more beneficial for people who are less independent, active and healthy; and who are more isolated: "I mean we're not in the position at the moment to need any of those things. But thinking of other people, I think it is marvellous". In line with previous findings [16], some older adults found it hard to imagine that they might feel less healthy in the near future and would need more assistance. Like Peek et al. [14], it was observed that many older adults talked about a hypothetical older person who could benefit from SONOPA, rather than themselves. However, eleven older adults indicated that they have no need for it at the moment, but could imagine to use it in the future, when they felt less healthy and active, or in case they would lose their partner. Some older adults found that the future SONOPA technology would not offer a lot of added benefits. Several older adults indicated to already use a paper diary for overlooking their appointments, or a pill-box to remember to take their medications. However, it also became clear that the concept of the technology was still quite abstract and therefore some of the participants did not fully understand all benefits the SONOPA technology could offer to them.

2) *Privacy, Obstrusiveness and Controle*: In line with previous studies [12][14][19][23], participants from both groups considered the loss of privacy as a negative aspect of the future SONOPA technology. Some of SONOPA's

potential functionalities were also regarded as intrusive. Several elderly participants felt that the SONOPA technology would invade their personal space, and that they would feel observed: “I think it is big brother, being watched all the time”. The older adults worried that they would feel restricted in their freedom and loose spontaneity: “But I don’t know whether you would creep around the house, thinking oh dear they can see me [...] That would be horrible, sort of spy on the wall”. Some of the older adults were concerned that the data could get in the wrong hands. However, the majority of the older adults found the idea of sensors acceptable because they perceived them to benefit their personal well-being and safety at home: “When I know that the sensors are installed in my home for my well-being, I don’t have any problems with them being in my home”. Earlier studies found that the loss of some privacy is an acceptable trade-off for safety and health [5][15][16]. Most older adults wanted to be able to switch the future SONOPA system on and off, be aware of which data are shared and decide with whom the data are shared. On the contrary, other participants thought that the system would only work to its full potential, when it could not be switched off. Furthermore, most of the participants who were comfortable with sensors, were comfortable to have them in every room of the house as “you can fall anywhere in the house”. However, a few older adults would not like to have sensors in the toilet, bathroom and bedroom.

3) *Lack of experience, technology anxiety and self efficacy*: The older adults were worried about the complexity of the future SONOPA technology. It was repeatedly emphasized that they did not grow up with technology and therefore, might lack the necessary skills, experience and confidence: “I think a lot of our generation are computer shy”. They were worried about the potential complexity of the interface, and how much user participation is needed to operate the system: “But if you got to go to an iPod thing and should do tututututu [push buttons] before you find out what you are supposed to do, that is not helpful”. Again, this confirms earlier findings [5]-[7][14][15][23][29].

4) *Social Stigma*: While assistance with chores was well perceived by a few older adults, others felt no need for assistance and almost felt insulted by the idea: “I don’t need anybody to tell me how to make a stew”. We observed that some older adults were very proud of their independence and therefore, rejected anything which would imply otherwise. Indeed, one older adult pointed out that seniors might be resistant to accepting that they need assistance and therefore, would not want to use technology that stigmatizes them as frail and dependent. This was also found by other researchers [5][6][14][19].

5) *Reliability*: Confirming earlier findings [5][6][14][15], older adults were concerned about the reliability of the future technology, especially the sensors.

They worried that SONOPA could give false alarms: “It might just go off with your natural things”. Two seniors regarded the activity recommendations as ineffective: “I am not convinced that a single technology application and especially a screen can motivate people to do stuff”. One older adult stated that the technology could even work the opposite way, by providing too much assistance and making people less active because then they do not have to go outside the house to have social contact: “It could be that you shackle them behind the computer”. Seniors also wondered if all parts of the system could be installed in different domestic environments: “I can’t honestly visualize it to be a possibility. Not in an old house”.

6) *Lack of Human Interaction*: Participants from both groups stated that SONOPA could not and should not replace human care and human interaction: “For me human contact is still most important [...] Thus, I prefer no computer”. Another participant said: “The negative point is that this person’s family and the environment cannot fully rely on this application. Because the application cannot replace the human”. This concern was also found in earlier studies [5][6][32].

7) *Cost*: Although cost came not up as a top-of-the-mind concern among the older adults, when asked about what they would be willing to pay for the SONOPA technology, it became clear that the technology has to be affordable for a person living on a pension. Several French and Belgium seniors demanded that the government would have to cover parts of the costs. Again, cost was identified as a critical issue in earlier studies [5][6][14][32].

## V. DESIGN GUIDELINES

Based on the findings from the literature study and the user-requirement study conducted within the SONOPA project, several design guidelines are formulated and discussed below.

### A. Clear, Specific and Flexible Benefits

To motivate people to use AAL technologies like SONOPA, it must not just offer added benefits, but at the same time those benefits have to be clear, specific and profound. Benefits which should be emphasized include: independence, safety, social involvement, support with ADLs, support of the care network and education and leisure. Keeping in mind that the intended target group is partially still very active and social, and therefore, might not feel an immediate need for an assistive technology, social, leisure and educational benefits should be further developed to target this segment. Because the concept of AAL technologies is often perceived as abstract, elderly should be able to try out or experience SONOPA without immediately being obliged to buy it.

### B. Ensuring Privacy, Security and Unobtrusiveness

AAL technologies like SONOPA contain sensitive data such as the personal activity patterns. Measures must be taken to ensure the security of this sensitive information. Privacy concerns can be reduced by giving the user control over whether the system is active, where the sensors are placed and which data are shared and with whom. However, user control has to be weighed against the proper functionality and reliability of the system. To avoid that people forget to switch the system back on, a time limit for deactivation could be applied. Furthermore, caregivers could be informed that the system has been switched off. To counter obtrusiveness, the technology and the sensors should be embedded in the elderly people's home environment and blend with the surroundings. The system should be able to communicate wirelessly and without noise, and not interfere with other devices in the home environment. For the social network element, the use of a closed network is recommended. Finally, it should be emphasized that the monitoring feature is for the sole purpose of the elderly person's health, safety and well-being.

### C. Simplicity and Familiarity

The interaction with the system should be simple, consistent and easy to use and learn. The SONOPA interface has to be intuitive and clearly structured. Technical slang should be avoided and textual elements should fit the elderly's frame of reference. The challenge is to create a simple design but not limit the functionality [23].

### D. Training and Low Level of Active Interaction

To simplify the interaction with AAL technologies like SONOPA, it is suggested to automate most processes and to opt for a minimal level of active user interaction, if desired by the user. Special training programs should be designed to teach the elderly how to use SONOPA and thereby improve the perceived ease of use and the confidence in their skills.

### E. Emphasizing Abilities rather than Disabilities

When designing and marketing AAL technologies like SONOPA, emphasis should be put on the abilities rather than the disabilities of the target group. This can be achieved by further developing and embedding social, leisure and educational features. SONOPA's functionalities should be helpful but not patronizing and be flexible to the wishes of the still healthy and active user.

### F. Reliability and Technical Support

Given that the average experience with technology in the elderly target group is rather low, robustness to mistakes is another important demand for designers to keep in mind. Furthermore, sensors should be accurate and reliable to avoid false alarms. Technical support in form of a helpline or a well-written manual should be available to all users to minimize technology anxiety and promote a successful interaction with the technology.

### G. Flexibility and Adaptiveness

AAL technologies like SONOPA should be adaptive to differences in physical constraints, personal preferences, technological skills, context and environment. By offering high flexibility in content, functionalities and level of control, SONOPA can appeal to the different needs of this highly diverse target group.

### H. Promoting not Replacing Social Interaction

AAL technologies like SONOPA should promote and not replace social interaction. For instance, it is recommended to use a local social network so that face-to-face interaction is a possibility.

### I. Low Cost and Spread Payments

Keeping in mind that the average income in parts of the intended target group is rather low, costs should fit into the available resources of the users. Also, a monthly payment scheme is recommended. Furthermore, one should keep in mind that users might expect that costs are partially covered by social security means.

## VI. CONCLUSION AND FUTURE WORK

AAL technologies can offer a promising solution to help elderly people to age independently in their own home environment, and at the same time control healthcare cost [5][6]. However, it is still uncertain if elderly people who are generally technology shy and have not grown up with technology will be ready to adopt these technologies [7][14]. This paper identified six benefits and eight barriers which are perceived by the elderly user with regard to assisted living technologies. Those benefits and barriers were found as a result of an extensive literature study and then supported and further specified by the findings of focus groups and interviews conducted within a user-requirement study. Together, findings led to the following design guidelines: (1) clear, specific and flexible benefits, (2) ensuring privacy, security and unobtrusiveness, (3) simplicity and familiarity, (4) training and low level of level of active interaction, (5) emphasizing abilities rather than disabilities, (6) reliability and technical support, (7) flexibility and adaptiveness, (8) promoting not replacing social interaction, (9) low cost and spread payments.

Our approach is not without limitations. The literature study did not follow a strictly systematic approach and therefore relevant articles might have been missed. However, a very recent systematic review on technology for aging in place was included [14]. Secondly, at this stage benefits, barriers and consequent design guidelines are based on qualitative data which were collected at an early project stage and with the use of only video scenarios. Therefore, these guidelines should be considered as an initial blueprint which will be further evaluated and specified as the SONOPA project matures.

Future work will focus on gathering quantitative data to further verify benefits, barriers and other factors relevant for the adoption of AAL technologies. Furthermore, instead of using scenarios a SONOPA prototype will be developed and evaluated in the field.

Although design guidelines need further specification, they form a valuable directive for the developers of SONOPA and other AAL technologies.

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