



User-Specific Concepts of Aging – A Qualitative Approach on AAL-Acceptance Regarding Ultrasonic Whistles

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Abstract. Against the background of demographic change, today's society is getting increasingly older. In order to handle growing care needs and shortages of skilled workers, ambient assisted living (AAL) technologies provide prevention and rehabilitation measures which facilitate aging in place and relieve caregivers. In this context, ultrasonic whistles could represent an innovative assistance system for home automation, safety prevention, positioning, and motion analysis. However, the acceptance of AAL-technologies is challenging due to perceived restrictions, e.g., on privacy and autonomy, and depends on individual attitudes, demands, and concerns. As health impairments and care dependency increase with age, research focus is set on age-related user factors. We examined user-specific concepts of aging in relation to the assessment of ultrasonic whistles in home care. For this purpose, semi-structured interviews and a scenario-based ground plan interaction were conducted. Results indicate that particularly positive or negative associations with aging affect AAL-acceptance, strongly related to issues of quality of life, active aging, social integration, dealing with change, health, and care dependency. Regarding trade-offs between perceived benefits and barriers, users with positive concepts of aging consider AAL as relief to maintain autonomy, ensure safety prevention, and facilitate everyday life whereas users with negative concepts of aging express concerns about dependency on technology, loss of control, restrictions on privacy, and data security. The findings contribute to an understanding of -aging concepts and their relation to care assistance that can be used for age-specific communication concepts.

Keywords: Ambient assisted living · Aging in place · Ultrasonic whistles
Technology acceptance · Qualitative approach

1 Introduction

Today, society is faced with major challenges due to global shifts in population structure, especially affecting the health care sectors [1]. In Germany, demographic change leads to a decrease in population as well as an aging society [2]. Compensation measures, particularly improved infrastructure and medical-technological progress

increase life expectancy and facilitate active aging. However, aging carries health restrictions, such as physical or mental diseases (e.g., cardiovascular disorders and dementia). Whereas the number of persons in need of care increases constantly, nursing staff decreases resulting in a lack of care [3]. Concurrently, many elderly people wish to stay at home as long as possible [4]. Against this background, aging in place gains in importance [5].

Considering home care, ambient assisted living (AAL) represents a promising approach to enable frail and elderly people to cope with daily routines independently and relieve caregivers. Next to single solutions (e.g., blood pressure monitors), holistic AAL-systems realize an interconnectivity of infrastructure in intelligent (smart) home environments [6]. In this context, ultrasonic whistles could represent an innovative assistance system which is flexible at use, retrofittable, and cost-effective. Central fields of application are home automation, safety prevention, positioning, and motion analysis [7, 8].

Particularly with regard to the users' perspective, the acceptance of AAL-technologies is challenging because of perceived restrictions, e.g., on autonomy and privacy. Thus, it is of great interest to which extent user-specific factors as well as their interaction affect AAL-acceptance. Previous research revealed a significant influence of user diversity, such as gender [9], age [10, 11], or experience with care [12]. Yet, the research intensity regarding technology acceptance-related concepts of aging is comparatively low. To the authors' knowledge, there have been no empirical findings related to ultrasonic whistles so far. Thus, in this study we focused on AAL-acceptance in relation to user-specific concepts of aging regarding ultrasonic whistles in home care.

In order to gain in-depth insights into the user-centered assessment, a qualitative research approach was chosen divided into two parts: First, semi-structured interviews were conducted in which the participants ($n = 9$) were asked to reflect their individual needs and demands concerning AAL. In particular, the interviews focused on user-specific concepts of aging regarding issues, such as quality of life, dealing with change, health, and care dependency. In a second step, a scenario-based ground plan interaction was conducted to identify perceived benefits and barriers as well as individual trade-offs concerning the use of ultrasonic whistles in home care.

2 Acceptance of Ambient Assisted Living

Given the fact that today's society is getting increasingly older, aging in place has become a socially relevant subject for research and practice to tackle long-term effects caused by demographic change, such as growing care needs and shortages of skilled workers. By definition, aging in place means "the ability to live in one's own home and community safely, independently, and comfortably, regardless of age, income, or ability level" [13]. In this context, ambient assisted living (AAL) provides reliable prevention and rehabilitation measures through technology assistance that enable elderly people to live actively, healthy, and autonomously in their own homes [14]. Since the use of AAL-technologies affects sensitive contexts and is more or less forced by health impairments, AAL-acceptance is challenging, especially with regard to

perceived restrictions on private life and autonomy. Thus, it is relevant to explore acceptance-related user factors for specific contexts of use.

In this chapter, we discuss AAL as a support for aging in place with special regard to ultrasonic whistles as an innovative assistance system. Next, AAL-technologies for aging in place are presented, before we outline (dis)advantages of existing technology acceptance models leading to a call for greater consideration of user diversity in this context. Then, age-related user factors are considered with particular attention to lacking knowledge about user-specific concepts of aging in relation to AAL-acceptance.

2.1 AAL-Technologies for Aging in Place

Concerning aging in place, one central observation is that elderly people demand choices about their living situation [4]. In the academic literature, particular attention is paid to individual senses associated with aging in place, such as social connection, security, and autonomy [4], user-specific perceptions of well-being [15], life satisfaction [16], and supportive housing solutions with special regard to AAL [17]. During the last decades, AAL-technologies have been evolving rapidly to fit particular contexts and needs [18]. Next to single solutions, e.g., blood pressure monitors and wheelchairs, there are multifunctional and modular assistance systems that can be integrated in supportive housing solutions (e.g., smart homes) unobtrusively, such as sensor technologies for home automation [19]. In general, smart homes are understood as “digital environments that are sensitive, adaptive and responsive to human needs” [18]. Relating to the idea of ubiquitous computing [20], holistic AAL-technologies provide possibilities to connect infrastructure in this context [6]. In particular, this includes assistance systems with high usability and ease of use that facilitate natural communication and interaction through language, gestures, and well-known interfaces, such as smartphones [21]. Central fields of application are medical monitoring (e.g., medication reminder and vital-parameter monitoring), safety prevention (e.g., floor sensors for fall detection), and home automation (e.g., automatic doors and lighting) [22].

Current research is marked by a growing drive for smart home solutions [23] to offset current impacts of demographic change, especially with regard to home care. In this context, ultrasonic whistles could represent an innovative assistance system offering opportunities for home automation, emergency service, positioning, and motion analysis to facilitate aging in place and relieve caregivers. Installation options relate to local fixations (e.g., wall switches) and wearable devices (e.g., emergency call button). As ultrasound is generated mechanically (e.g., via button press), without using electricity or batteries, its environmentally sustainable energy supply is to be mentioned as a key feature [8]. Thus, ultrasonic whistles make it possible to reduce environmental impacts which often correlate with other wireless assistance systems caused by used batteries. By actuation, acoustic signals coded by frequency are generated that are inaudible to human ears. Decoding takes place by receiving devices, installed in ceiling lights, for example, that activate required functions and forward data to family caregivers, nursing services, or emergency centers. Beyond these technical possibilities of ultrasonic whistles, their acceptance by potential users has not been investigated so far.

2.2 Technology Acceptance and User Diversity

With regard to the user's perspective, the acceptance of AAL represents a major challenge and cannot be simply presumed. Thus, it is observable that AAL-technologies are considered useful but are rejected at the same time due to perceived restrictions, e.g., on autonomy and privacy [24].

Within technology acceptance research, diverse models have been developed in the last decades to evaluate and measure acceptance and perceptions of technologies and systems. Defined from the conventional modelling point of view, technology acceptance strongly depends on two main factors: perceived usefulness and perceived ease-of-use [25]. Although there have been numerous developments, leading to more and more adaptations and upgrades of acceptance models, e.g., TAM1 to TAM2 to TAM3 [e.g., 25, 26], UTAUT 1 to UTAUT2 [e.g., 27, 28], these models still focus on a restricted number of influencing parameters leaving specific motives and concerns of potential users largely aside. As technologies are highly diverse in the area of AAL, e.g., comparing medical with computer technologies, classical factors from technology acceptance models do not only differ for the type of technology but also with regard to user diversity [29, 30]. However, existing acceptance models are only limited suitable for the evaluation of specific AAL-technologies due to several reasons: on the one hand, the number of integrated technology-related aspects is rather low and disregards technology-related benefits or concerns; on the other hand, this is also true for the range of model-integrated user-related aspects beyond demographic characteristics (personality traits such as the attitude towards aging). Thus, a qualitative and exploratory research approach (see Sect. 3) is necessary to identify and gain insights into acceptance-relevant criteria with regard to a very specific and innovative AAL-technology – an ultrasonic whistle (see Sect. 2.1).

Considering the ultrasonic whistle for AAL purposes, the focus of this study lies on an evaluation of a specific AAL-technology for older adults. Previous studies revealed that indirect surveillance technologies such as a positioning system are in general more accepted than direct technologies, e.g., cameras or microphones [31]. From the technical point of view, we also need a microphone installed in the rooms in order to measure the ultrasonic sound signals, which could lead to acceptance barriers [9]. Explaining future users that the microphones only measure frequencies inaudible for human beings could easily dissolve these barriers, as long as they trust in the manufacturer, which is also an often-mentioned acceptance factor [32].

The technology evaluated in this research is usable for two main purposes concerning different acceptance barriers: on the one hand, for smart home input to control for example room temperature, window and door opener, or start communication devices, which do not represent critical acceptance issues for older adults [33]. However, the second application purpose for the ultrasonic whistle is to use them as a tracking device, either installing it in the floor of different rooms or directly into shoes or furniture. As already cited, acceptance for ambient positioning systems for assisting purposes on the one hand leads to several acceptance issues regarding surveillance and privacy, but on the other hand, it is less affected by the rooms, where it is installed, compared to other technologies [31]. Therefore, the acceptance research for the ultrasonic whistle technology strongly focusses on “where” to use them and on

identifying perceived benefits and barriers for this specific technology out of the users' perspective. Finally, it is important to understand acceptance for the specific user group, "who" will be supported – in our case older adults potentially in need of care. However, "old" itself does not automatically implicate "needy" [34] neither does it go vice versa. Hence, we have to understand aging as a more complex user factor concerning the acceptance of specific AAL-technologies [4, 10].

2.3 Age-Related User Factors

Concerning the growth of a graying society aging needs to be considered as a highly heterogeneous and individual process [4]. Hence, research intensity concerning age-related user factors has been high, particularly with regard to biological age and general attitudes towards aging [10, 31, 34, 35]. Key findings demonstrate that elderly people are truly willing to use AAL-technologies, unlike popular stereotypes [10, 31, 34]. However, older generations tend to have lower levels of expertise and confidence concerning the use of technical devices compared to younger generations [35]. In addition, for older adults, the use of innovative technology is not a benefit per se, but is only accepted if technology is developed in line with individual requirements and, when older adults consider technology as useful [30, 31]. Thus, it is even more important to explore individual attitudes, concerns, and demands concerning the use of AAL-technologies in order to reduce potential barriers for greater access and usage at older age.

In addition, previous results indicate a relationship between attitudes towards aging and AAL-acceptance, especially with regard to age- and gender-specific differences concerning quality of life [35]. However, research on acceptance-related concepts of aging (in place) is comparatively low [5]. Yet, there have been no empirical findings concerning the assessment of ultrasonic whistles in home care related to user-specific perceptions of aging so far.

3 Research Approach

This study aimed at exploring user factors which affect the assessment of AAL concerning ultrasonic whistles in home care, with special regard to (1) user-specific concepts of aging and (2) perceived benefits and barriers. Due to a gap in research concerning the user-centered assessment of ultrasonic whistles, we chose a two-step qualitative approach, consisting of semi-structured interviews and a scenario-based ground plan interaction.

The survey was conducted in Germany during May 2017. In order to gain application-centric insights the participants ($n = 9$) were interviewed in their home environments. The language spoken was German. First, information about the procedure and privacy policy were given. Then, a short questionnaire concerning demographic data (e.g., age, gender, health status, and medical assistance) was handed out. On average, the overall duration lasted between 60 and 90 min. The interviews were recorded auditory and transcribed verbatim. The ground plan interaction was filmed under the condition that the viewing direction was limited to the drawing to guarantee

the participants' anonymity. The material was evaluated by means of qualitative content analyses [36]. Research categories were established inductively and complemented deductively with special regard to acceptance-related constructs in this context, such as data security [37].

Within this chapter, an overview of the empirical approach is given. First, characteristics of semi-structured interviews are discussed, before the interview guideline is presented in detail. In a second step, the scenario-based ground plan interaction is outlined. Then, characteristics of the participants are considered.

3.1 Semi-structured Interviews

According to communication sciences, qualitative methods are often used to carry out surveys on under-explored research fields in early stages of investigation to discover relevant issues linked to research [38]. On the basis of the collected data, it is then possible to formulate research questions for further validation in subsequent quantitative approaches [39].

In this study, an exploratory research approach was chosen due to lacking empirical findings concerning the user-centered assessment of ultrasonic whistles in home care. Particularly with regard to AAL, as it refers to sensitive and highly personal issues, such as aging, health, and care dependency, personal interviews represent a reliable method to gain in-depth insights into acceptance-related attitudes, concerns, and demands [40]. For this reason, we conducted semi-structured interviews, based on a guideline with open questions in flexible order. The aim of the interview survey was to explore general attitudes towards AAL in home care, with special regard to user-specific concepts of aging. In particular, we focused on middle-aged (>40) and elderly (>70) people who came into question as potential users of ultrasonic whistles, either as caregivers or patients. All respondents were given the opportunity to answer freely and participate actively by providing own contents and ideas that may not have been covered through the interview guideline. If possible, the selected target groups were interviewed in turns in order to gain detailed and improved knowledge by changing perspectives, especially with regard to subjective perceptions (e.g., knowledge, experience, and attitude).

3.2 Interview Guideline

The development of the interview guideline was based on literature review according to the current state of research. By means of a pretest, the wording was slightly modified for better comprehension. Next, key issues are presented in detail.

Initially, thematic sections with regard to the participants' general use of technology and technical expertise were established in order to obtain an overall picture of acceptance-related opinion and mood. In this context, the participants were asked to assess their technological skills. The self-report based on a 6-point Likert scale (1 = "disagree strongly"; 6 = "agree strongly") concerning 4 items measuring internal and external factors when dealing with technology [41].

In particular, we focused on user-specific concepts of aging. First, participants were asked to state personal ideas, needs, and concerns with regard to aging (e.g., "What

comes to your mind when you think of aging?”). Next, issues concerning quality of life and dealing with change were considered (e.g., “How do you see life at older age?” and “How do you handle changes in life?”). Then, it was discussed whether and to what extent the participants were generally willing to accept/offer assistance from/to others. In connection with that, we addressed personal experiences with home care (e.g., “Have you ever required home care by yourself?” and “Can you imagine taking care of somebody at home in the future?”). Finally, the participants were asked where and for what reason they would like to live at older age.

Furthermore, we aimed at exploring general attitudes towards AAL in home care. In order to ensure that all participants had the same level of knowledge in this context, we provided a short scenario in which the participants were to imagine that themselves or relatives are in need of care. Next, we presented different AAL-technologies and applications, e.g., blood pressure monitors for medical monitoring, wheelchairs for motion analysis, and audiovisual systems, such as microphone and camera, for health and safety prevention. At first, the participants were asked about their general knowledge and previous experience concerning AAL (e.g., “Which medical assistance systems do you know?” and “Which AAL-technologies have you used yet?”). Then, we asked whether and to what extent AAL was considered useful. In connection with that, general (dis)advantages were discussed in order to identify situational factors, conditions, and purposes for the use of AAL in home care (e.g., cost effort, usability, and safety) with special regard to different user groups (patient versus caregiver).

3.3 Ground Plan Interaction

Subsequent to the semi-structured interviews, a scenario-based ground plan interaction was conducted, with particular attention to perceived benefits and barriers concerning the use of ultrasonic whistles in home care. At this, the participants were asked to draw a ground plan of their home environment in DIN A3 format containing frequently used rooms (e.g., bathroom, living room, and bedroom) and everyday objects (e.g., doors, chairs, and textiles) (see Fig. 1).

Since ultrasonic whistles represent an innovative assistance system, the participants were informed about technical core features and application options regarding home care. In addition, we provided a prototype for better comprehension in order to reduce remaining uncertainties. Then, a short scenario was introduced in which the participants, again, were to imagine that either themselves or relatives are in need of care. Next, they were asked to indicate locations in which they would accept or reject the use of ultrasonic whistles with regard to particular applications. Here, the focus was set on the assessment of different installation sites (rooms) and types (fixed installation and wearable devices) related to the pictured ground plan, e.g., bedroom versus living room, wall switches for home automation versus smart textiles for motion analysis. The assessment followed a two-step procedure: First, the participants were asked to assess whether and to what reason the different installation options were (not) considered useful. Then, they were asked whether they would accept or reject the respective application in question. For visualizing assessment results, multicolored post-it’s were used. The color green represented technology acceptance whereas the color red

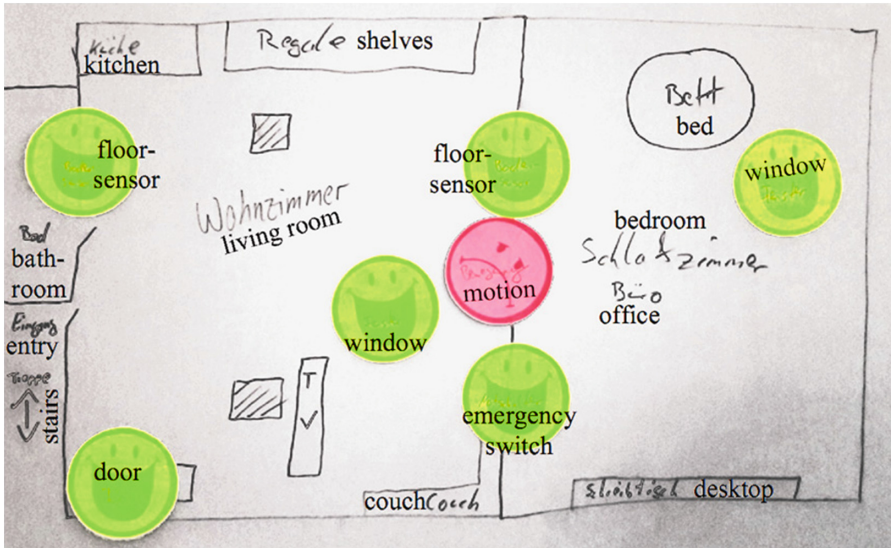


Fig. 1. Exemplary ground plan drawing. (Color figure online)

indicated technology rejection (see Fig. 1). In addition, the color yellow was made available to demonstrate abstention or rather indecisiveness.

Besides, we discussed perceived (dis)advantages of ultrasonic whistles in home care with special regard to data security in order to explore further issues that determine the assessment (e.g., “Does it make a difference to you who may gain insights into your data?”). Concluding, the participants were faced with a final decision concerning the acceptance or rejection of ultrasonic whistles in home care considering (1) personal situations of care dependency, (2) the support and care of relatives, and (3) the present time.

3.4 Participants

Since the probability of care dependency increases at older age and the role of family caregivers gains in importance currently, the sample was selected with special regard to elderly (>70) and middle-aged (>40) participants. A total of nine people (5 male; 4 female) participated in the survey, aged between 24 and 84 years ($M = 58.7$; $SD = 18.8$). The participants were recruited through personal contacts in order to create a sound basis of trust without payment or other gratification.

The majority was living alone or in multigenerational housing and was not dependent on home care, due to acute or chronic diseases for example. In total, five participants made use of medical assistance systems, predominantly blood pressure monitors. In general, the survey revealed high self-assessments when dealing with technology ($M = 4.18$; $SD = 1.00$; $Min = 1$; $Max = 6$).

4 Results

This study's aim was to explore user-specific concepts of aging in relation to AAL-acceptance with special regard to perceived benefits and barriers concerning ultrasonic whistles in home care. First, general assessment results are presented, before we outline acceptance-related perceptions of aging. Then, intentions to use ultrasonic whistles in home care are considered, particularly individual trade-offs between perceived benefits and barriers.

4.1 General Assessment of AAL in Home Care

In general, AAL was considered useful according to the patient's safety and the support of caregivers. However, perceived restrictions, particularly on autonomy and privacy, reduced the overall acceptance of AAL-technologies. In comparison to other contexts of use, such as information and communication technologies (ICT) for facilitating everyday life and entertainment (e.g., kitchenware and smartphone), the use of AAL was regarded necessary due to physical or mental restrictions. Thus, it was observable that medical assistance was considered helpful but was rejected at the same time, especially with regard to ultrasonic whistles in home care. According to care situations, human surveillance was generally rather accepted than technical monitoring due to personal discomfort and mistrust when dealing with technology as the following statement shows:

"Well, a nursing service that drops in feels more pleasant. So, if you ask me, personal care is definitely better than being watched by cameras." (male, 24 years)

However, assessment results indicated that participants are more willing to accept technological assistance if this means that they can live at home for as long as possible. Considering the use of AAL-technologies, personal experience was limited to single solutions, predominately blood pressure monitors. Regarding holistic AAL-systems, there was only little knowledge. In particular concerning external monitoring, most of the participants expressed concerns caused by the feeling of losing control.

"Why shouldn't you use all of the means available? But as I said: Personally, I would clearly distinguish between bath lifts and microphone monitoring." (male, 44 years)

In addition, assessment results showed differences with regard to the users' role. One central observation was that participants who considered themselves as caregivers perceived AAL as relief and were more willing to accept AAL-technologies in home care.

"For professional reasons, I know that nursing is physical demanding for both sites, patient and caregiver. That's why I would appreciate technological assistance in home care." (female, 51 years)

Contrary, participants who expected to be personally affected by the use of technology assistance due to physical or mental diseases rather stated rejection, explained in terms of an uncomfortable feeling of dependency.

"Well, in that case, I prefer lying on the floor." (male, 44 years)

4.2 Acceptance-Related Concepts of Aging

Above all, assessment results revealed high impacts of user factors on the acceptance of AAL in home care, with special regard to user-specific concepts of aging. On the basis of the material, concepts of aging were defined as associations with aging that influenced subjective perceptions positively or negatively, highly related to the categories *quality of life*, *active aging*, *social integration*, *dealing with change*, and *health and care dependency*. Key findings indicated that participants associating positive concepts of aging rather tended to accept the use of AAL-technologies in home care than participants stating concerns about aging.

Particularly, ideas concerning *quality of life* that are related to individual needs and demands for personal well-being determined the perception of aging. Central ideas referred to *good health*, *autonomy*, *unrestricted mobility*, and *financial security*.

"How I consider quality of life? Feeling fit and healthy, so that I am capable to move on my own. And that I am not dependent on others, in any way." (male, 24 years)

Conversely, physical and mental impairments, dependence on others, less activity, and poverty in old age were experienced as reductions of quality of life leading to negative perceptions of aging.

"To me, aging stands for physical restrictions, less mobility, and a loss of continuity due to retirement." (male, 58 years)

In line with central aspects regarding quality of life, *active aging* was a great influential factor. Corresponding concepts mainly related to *independence in everyday life*. Especially the wish to continue participating in *social activities*, such as fitness and travels, was often expressed and affected the perception of aging in positive ways.

"Life satisfaction means that I can live life as I want to, self-determined, and independent. That I can continue travelling and will keep in close contact with family and friends at older age." (female, 52 years)

According to later housing situations, the majority preferred to *live at home autonomously* for as long as possible. In this context, *social integration* was made a subject to discussion referring to a growing *need for community* in order to "*make oneself useful*" and "*help each other*" at older age. In particular, *local integration* provided a sense of *safety* and *familiarity*.

"At home, I am surrounded by nice and friendly people who I could ask for help at any time. [...] In case that I get into a care situation, I can rely on family persons of trust." (female, 84 years)

As the above-mentioned statement demonstrates, some participants were confident to receive support from relatives at older age, depending on respective family situations. However, others expressed concerns about "*being a burden*" to family and friends as well as fears regarding social isolation due to childlessness or deceased relatives. Thus, they were more willing to move to a nursing home.

"I hope that I can stay at home for as long as possible in the first place. But if I am no longer in a position to look after myself, I'll move to a nursing home without hesitation." (male, 81 years)

In general, *dealing with change* was considered as extent to which people respond positively or negatively to changing life situations. Particularly, sudden changes had negative connotations. Still, some participants considered *change as an opportunity* for new experiences and possibilities towards more leisure time, for example. Thus, they remained positive, optimistic, and cheerful.

“I learned to accept few restrictions. Using the stairs isn’t that easy anymore. Things take more time. But I deal with it. I can still handle things alone.” (female, 84 years)

In contrast, others were strongly concerned about changing life situations, predominantly by expecting health restrictions and lethargy at older age. In this case, participants considered *change as a threat*.

“I am sure, that serious life restrictions will come to pass. In my experience, it is very rare that people are still fit in their eighties. Something’s gonna happen. [...] Something that changes things permanently.” (male, 24 years)

In consideration of various aspects associated with concepts of aging, *health and care dependency* represented recurring issues. Particularly, current *health status and experiences with health restrictions* gained an influence on the perception of aging. Thus, participants in good health were confident to remain fit at older age whereas participants who personally experienced health impairments and restrictions on mobility considered aging in pessimistic ways, explained in terms of dependency.

“Generally, the feeling of dependency is harder to bear than offering help to others.” (male, 70 years)

With regard to the user’s perspective, a trend could be seen that especially general attitudes and characteristics determined corresponding concepts of aging, next to family situation and personal experience, for example. Thus, participants who were optimistic and open to change rather associated positive concepts of aging than participants who tended to have pessimistic and skeptical attitudes.

4.3 Intention to Use Ultrasonic Whistles

Concerning the intention to use ultrasonic whistles in home care, particular applications in question were mainly discussed in the categories *room*, *function*, and *location*. With regard to installation sites (*rooms*), the use of ultrasonic whistles was rather accepted in public rooms, such as living room, than in private rooms due to perceived restrictions on *private life*, particularly in bath- and bedroom.

“I don’t see any problem regarding desktop or dining room, for example. But especially bedroom and bed depict very private zones.” (male, 58 years)

Concerning different *functions*, applications for home automation were often approved in order to *facilitate everyday life* whereas positioning and motion analysis were usually rejected caused by a “*feeling of being watched*”. Due to commonly high *safety needs*, emergency functions were prioritized, particularly arm straps for emergency calls.

“To me, such a system should be easy to handle [...] and visibly worn on the body, like a wristband for emergency calls. That I would use.” (female, 84 years)

In general, the assessment of installation types (*locations*) depended on particular functioning, as the before mentioned statement demonstrates. Next to *wearable devices* for safety prevention, *fixed applications* for home automation located in wall switches, doors, windows, or cupboards were rather accepted than installations for positioning, e.g., on beds, sofas, and floors, except for thresholds and stairs due to perceived risks of falling. The use of ultrasonic whistles in *smart textiles*, such as shoes, for movement analysis was generally rejected.

“Literally, each step is closely monitored.” (female, 52 years)

One central observation was that participants were more willing to use AAL-technologies with an increasing level of care dependency. Conversely, at the present time, the use of ultrasonic whistles was refused.

“Right now, I feel restricted. [...] But when in need of care, it isn’t only necessary to feel observed, but instead to be observed, so that help can be provided quickly. Then, I would accept it.” (female, 84 years)

Perceived Benefits and Barriers. Above all, the study revealed that autonomy, privacy, control, and data security depict acceptance-related key determinants. Perceived benefits and barriers are pictured in Figs. 2 and 3.

With regard to perceived *benefits* (see Fig. 2), the *preservation of autonomy* and *safety prevention* provided a strong motivation to use ultrasonic whistles, especially at older age.

“When in need of care, such a system should be integrated everywhere. I don’t know where I will tumble.” (male, 81 years)



Fig. 2. Perceived benefits concerning the use of ultrasonic whistles in home care.

Especially home automation and emergency service were considered as opportunities to live at home for as long as possible. In this connection, *multifunctional features* were discussed as further advantages. Considering the facilitation of everyday life, *saving of time* along with *preservation of mobility* and *physical relief* were considered as good reasons for ultrasonic whistles in home care, especially mentioned by participants who experienced health restrictions or care dependency personally.

“Well, for health reasons. To take care of oneself. Time saving, as well. And to provide a certain safety, I guess.” (female, 51 years)

Other perceived benefits referred to the energy supply and design of ultrasonic whistles. In this context, particular attention was paid to *independence of electricity and energy, environment protection*, and the comparatively *unobtrusive design* which was regarded as protection from stigmatization.

“A major advantage is that they’re independent of an energy supplier. [...] Another benefit is that they’re small and light. It seems that even physically restricted persons can push it.” (male, 44 years)

Contrary, with regard to perceived *barriers* (see Fig. 3), particularly *restrictions on autonomy and privacy* represented general reasons to reject ultrasonic whistles in home care, especially considering external monitoring by positioning and movement analysis.

“It gives you security, of course. But to me, that’s like complete monitoring.” (male, 24 years)



Fig. 3. Perceived barriers concerning the use of ultrasonic whistles in home care.

In many cases, the feeling of *“being dependent on technology”* led to the fear of *losing control*. In this context, especially concerns about *transferring data to third parties* and *data misuse* were expressed.

“This ‘out of house dimension’ is striking. I would be more skeptical in this context than towards technical simplifications that make daily life possible again.” (male, 70 years)

Another subject brought do discussion was *social isolation* due to the assumption that technology usage reduces social contacts, as for example nursing service is less needed. Regarding the technological function of ultrasound, some participants came up with doubts concerning *error rates caused by acoustic disturbances* which may limited the acceptance. Others rejected to use of ultrasonic whistles at all, explained in terms of *“useless”* or *“outdated”* compared to equivalent technologies, e.g., RFID.

“I am not convinced by this technology. [...] I would rather prefer a multifunctional device that is fixed on my body permanently.” (female, 65 years)

Against the background of expected poverty in old age, general concerns about *private funding* were mentioned. Further barriers referred to *restrictions on aesthetic demands*, with regard to retrofitting and renovation work.

Trade-off Effects. Trade-offs between perceived benefits and barriers indicated whether and to what extent users were willing to accept compromises concerning the use of ultrasonic whistles in home care personally. In detail, assessment results showed user-specific differences, especially with regard to subjective perceptions of aging and personality traits in this context. Thus, it was observable that optimistic participants with positive concepts of aging tended to focus on perceived benefits when dealing with AAL in home care. In particular, safety prevention and the preservation of autonomy outweighed perceived restrictions on privacy, for example.

“I feel unwell, especially regarding bed- and bathroom. I don’t wanna share private and intimate areas with others. But if it helps to stay at home autonomously, I would accept any assistance.” (female, 51 years)

Contrary, pessimistic participants with negative concepts of aging, in particular concerning changing life situations, gave priority to perceived barriers. Especially with regard to dependency, they tended to emphasize foreign control and restrictions on data security, often leading to the conclusion to rather distrust technology.

Respondent: “I just don’t like the feeling that a foreign knows about my habits, in any form. [...]” (male, 24 years)

Interviewer: “[...] So you would rather take the risk of lying in bed and not being found than that someone knows where you are? [...] Both now and in the future?”

Respondent: “Yes, definitely.”

In addition, age-related differences were observable. Thus, elderly people rather focused on usability issues, e.g., ease of use and language of instruction, due to comparatively low technical expertise and little knowledge of foreign languages whereas younger participants prioritized work-life-balance, for example.

5 Discussion

The aim of this study was to reveal insights into the user-centered assessment of ultrasonic whistles in home care with special attention to user-specific concepts of aging as well as perceived benefits and barriers. Overall, the outcomes indicate decision trends concerning installation sites and types, strongly related to particular functions. In detail, the assessment results show an influence of user diversity, particularly with regard to subjective perceptions of aging. One central observation is that people who associated positive concepts of aging were more willing to accept AAL-technologies than people who expressed negative attitudes towards aging. Next, user-centered assessment results are discussed, before we outline limitations and future research.

5.1 User-Centered Assessment of Ultrasonic Whistles

Overall, assessment results indicate that the use of AAL-technologies is considered necessary caused by health restrictions, especially compared to other contexts of use, such as ICT for information, communication, and entertainment. Personal experience

with AAL is limited to single solutions, such as blood pressure monitors and wheelchair whereas the knowledge about holistic systems is comparatively low. In this context, participants expressed concerns in terms of “*being watched*” and “*losing control*”. However, there is a distinction between different technologies. In line with [31], audiovisual monitoring (e.g., microphone and camera) is least accepted.

Regarding the use of ultrasonic whistles in general, home automation is more likely accepted than positioning and motion analysis, even across room boundaries. Considering single installation sites, participants expressed strong needs for safety prevention in bath- and bedroom. However, perceived restrictions on private life limited the acceptance in this respect. In contrast, the use of ultrasonic whistles in public rooms, such as living room and office, is rather accepted which also confirms previous research [31]. Overall, emergency service provides the strongest motivation to use ultrasonic whistles, especially concerning wearable devices. Though, most of the participants expressed the wish for self-determination and control options when dealing with AAL-technologies for as long as possible.

Considering the intention to use ultrasonic whistles, autonomy, privacy, control, and data security depict key determinants, similar to previous results on AAL-acceptance, e.g., [37, 42]. With regard to the users’ perspective, the results obtained show user-specific differences, particularly depending on subjective perceptions of aging and personality traits, such as extraversion, neuroticisms, and openness. In contrast, gender and biological age seem to have a minor influence.

In this study, we examined quality of life, active aging, social integration, dealing with change, health, and care dependency as key categories revealing either positive or negative concepts of aging (“*aging as an opportunity*” versus “*aging as a threat*”). In line with [4, 15, 35], aspects of quality of life related to social life, independency, health, and control in personal space depict central issues for discussion. Summarizing, positive concepts of aging picture optimistic expectations regarding high quality of life along with possibilities for living independently, active aging, fairly well health, and social inclusion. Conversely, negative concepts of aging are associated with fears concerning reductions of quality of life, particularly due to expected physical and mental diseases, restricted mobility, dependency on others, and social isolation. Key findings reveal a relationship between user-specific concepts of aging and technology acceptance, particularly with regard to trade-offs between perceived benefits and barriers concerning ultrasonic whistles in home care. Thus, participants with positive concepts of aging, who were optimistic and open to change in general, rather considered AAL as a relief in order to maintain autonomy, ensure safety prevention, and facilitate everyday life. Hence, they tended to emphasize perceived benefits to outweigh potential barriers. In contrast, participants with negative concepts of aging, who rather had pessimistic and skeptical attitudes and regarded age-related changes as a decline, predominately expressed concerns about being dependent on technology, loss of control, restrictions on privacy, and data security. As a result, they gave priority to perceived barriers and decided against the use of ultrasonic whistles in home care more often. In addition, with regard to the users’ role, the degree to which people were affected personally seemed to be important. Thus, participants who imagined themselves as caregivers rather considered AAL useful than participants who considered themselves as future patients.

Concluding, the empirical findings indicate that particular functions as well as installation options affect the intention to use ultrasonic whistles in home care, strongly connected to user factors. This study's outcomes formed the basis for further analyses within a quantitative questionnaire study in progress, particularly focusing on acceptance-related concepts of aging in correlation with personality traits, age, and technology acceptance.

5.2 Limitations and Future Research

Overall, the qualitative survey revealed in-depth insights into the user-centered assessment of ultrasonic whistles in home care. However, there are study limitations which are discussed in connection with postulations for future research below.

First, with regard to the research approach, the two-step procedure revealed a disparity between assessment results. It was observable that most of the participants expressed concerns about safety risks and strong needs for prevention measures within the semi-structured interviews whereas they tended to reject appropriate applications during the ground plan interaction, especially with regard to private rooms due to perceived restrictions on personal space. This indicates that methods and research objects are interconnected and leads to the assumption that some factors are more context-sensitive than others. Our findings are comparable with previous research focusing on user-centered assessments in correlation with different research models [43]. In line with [43] a multi-method approach is suggested in order to explore overall acceptance factors. Particularly with regard to our scenario-based research design, assessment results may differ under experimental conditions, such as real-life smart home environments.

Furthermore, personal contacts provided profound insights. Though, assessment results may be biased as the participants could have responded differently in order to match presumed expectations. Additionally, the small sample size does not allow a generalization of results. Thus, key findings should be validated in future research considering a broad sample and quantitative methods. Besides, participants should be recruited with special regard to different user groups (caregivers versus patients) in order to examine user-specific differences in the assessment, particularly according to perceived benefits and barriers.

All things considered, our assessment results are limited to the cultural background of Germany related to specific norms and values as well as a particular health care system. Thus, it is of great interest whether and to what extent assessment results may differ on an international comparison.

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