# Living with Disabilities – The Many Faces of Smart Home Technology Acceptance

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**Abstract.** To face the challenges of increasing care needs due to demographic change, the development of smart home and Ambient Assisted Living (AAL) technologies present one approach, which is continuously forwarded. Besides aspects of technical development and implementation, user acceptance of diverse stakeholders plays a major role for a successful rollout and sustainable adoption of those technologies. So far, user acceptance research in this context has concentrated mostly on age-related issues. In contrast, disabilities and related care needs have hardly been researched yet. The current study focused on persons having different experiences with disabilities and care needs. In a qualitative interview pre-study (n = 9) and a follow-up quantitative online questionnaire study (n = 279) perceived benefits and barriers, use conditions, and acceptance of AAL technologies were contrasted. Four user groups were under study: disabled participants, relatives of disabled persons, professional caregivers, and, as a control group, persons without experience with disabilities. Results indicate that disabled and care-needy people show a higher acceptance and intention to use an AAL system than not-experienced people and especially professional caregivers. The motives for acceptance and rejection differ strongly regarding user diversity as well. The results contribute to a better understanding of user-specific acceptance of smart home and AAL technologies and show that the integration of diverse user groups into the technologies' design and evaluation process is necessary.

**Keywords:** Technology acceptance · User diversity
Ambient assisted living (AAL) · Smart home technologies
Needs of assistance and care · Experience with disabilities

## 1 Introduction

Diseases and disabilities are omnipresent challenges for today's society. Particularly in the context of demographic change, a steadily increasing number of older people and people in need of care pose strains for the care sectors [1, 2].

Coincidently, most of the older people desire to live at their own home as long and as autonomously as possible [3]. Hence, connected with the rising age of people and their willingness to stay at home as long as possible, age-related diseases (e.g., cardiovascular diseases, diabetes, or dementia) are greatly relevant and rise continuously [4–6]. However, they represent only one side of the coin as age-independent diseases


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and disabilities are also of importance causing huge needs of care and assistance as well [7]. Further, a new phenomenon of a first generation of "old and disabled" people needs to be taken into account: on the one hand, this development is enabled by medical and technical innovations in healthcare, e.g., new medicines and inventive therapies; on the other hand, this development is also influenced by the specific historical background of euthanasia offenses (especially in Europe), in which disabled people were systematically aborted, deported, and even murdered [8].

Summarizing, age, diseases, as well as disabilities must be considered while analyzing increasing needs of care and related challenges. Yet, there are technical single-case solutions and complex ambient assisted living (AAL) or smart home technology systems [9] that address these challenges. These developments already enable systems that monitor (medical) parameters, detect falls and positions, or facilitate living at home using smart home technology elements [10–12]. Besides technical single-case solutions, current research focuses also more and more on holistic systems, that unite different functions and are especially adaptable to individual needs of diverse user groups.

To realize technical systems that meet the requirements of diverse user groups, it is necessary to analyze whether, to which extent, and under which conditions such systems are accepted and also to what extent those evaluations depend on user factors. So far, there have been several studies investigating the acceptance of AAL and smart home technologies focusing on influencing demographic factors such as age (e.g., [13, 14]) or gender [15]. As disabled people have hardly been considered yet, this paper analyzes the acceptance of AAL systems with focus on people having different perspectives and experiences with disabilities.

## 2 Smart Home Technologies and Acceptance

This section illuminates the technical and acceptance-relevant historical background for the underlying research approach. First, the most important developments concerning AAL and smart home technologies are summarized. Further, key aspects of the theoretical background with regard to technology acceptance research is presented focusing on potential influencing user diversity factors. Finally, an overview of current acceptance research on AAL systems and the starting point for the underlying research approach are given.

In the last decades, the use of Information and Communication Technologies (ICT) in everyday life has been studied [16] and different options of monitoring are enabled by integrating ICT (e.g., microphones, cameras, and movement sensors) into people's living spaces. To date, the amount of commercial smart home technology systems as well as smart home and AAL research projects increased continuously. These systems enable smart home functions (e.g., sensors for lighting and heating control, sensors for automatic opening of doors and windows), fall detection as well as other health care applications (such as a reminder for drugs or blood sugar measuring) and are available for an integration in home environments (e.g., [17, 18]), hospitals [19], and nursing homes [20]. Different research projects focus on the development of holistic systems as well (e.g., [21, 22]) and some of these projects attach importance to integrate future users (in most cases older people) iteratively in the development

process [23]. As the users' perspective is decisive for a successful integration of technologies in their everyday life, a user-centered design and development is necessary. Until now, smart home and especially AAL technologies are not systematically integrated in private home environments (in contrast to professional care contexts), although they have the potential to facilitate the everyday life of older, diseased, or disabled people. To understand the perception of smart home technology systems (and underlying usage motives and barriers), potential users and their perceptions, their mental models about aging as well as their wishes must be focused.

So far, smart home technologies have mostly been perceived and evaluated positive, while especially the necessity and usefulness of technical support have been highly acknowledged [22, 24]. Within these evaluations, the possibility of staying longer at the own home and an increased independency are relevant motives to use smart home and AAL systems. In contrast, the most relevant concerns and acceptance barriers deal with feelings of social isolation (e.g., [25]) and surveillance as well as invasion of privacy (e.g., [26]) if people were asked to think about a concrete integration of a system in their living environment.

To comprehend the trade-off between perceived benefits and barriers, analyses of technology acceptance and user diversity are needed considering not only traditional technology acceptance models (e.g., TAM and UTAUT) as they have been developed in completely different contexts and might thus not be applicable. In contrast to conventional ICT, smart home technology and AAL systems address especially older, diseased, and frail people with individual requirements, wishes, and concerns [27]. Hence, we assume that those specific user groups weight perceived benefits and barriers differently and show diverse acceptance patterns concerning assistive technologies and systems. In the following, an overview of acceptance research findings focusing on user diversity and different user group perspectives is presented.

To understand the elderly's perception of smart home and AAL technologies, numerous focus groups [28, 29] and interviews [24] with people (aged above 60 years) show similar recurrent results: perceived benefits in terms of staying longer at home, understanding the imminent lack of care staff, and the chances of AAL technologies contrast with concerns about dependency on technologies, the lack of personal contact as well as data security and privacy (e.g., [30]). Additionally, recent projects on smart home and AAL labs, e.g., Soprano [21], Philips Research Care Lab [31], eHealth Future Care Lab [32], have understood to integrate particularly older users into the design, development, and evaluation processes.

So far, previous research for smart home and AAL technologies has focused on elderly people with age-specific illnesses. In contrast, the acceptance of such technologies for disabled persons still needs more and specified research attention. While such assistive technologies could be specifically useful to support the inclusion of people with disabilities into society, to improve mobility and communication as well as to hold down a job, nearly any study so far investigated age and disability in depth. Some studies analyzed how diverse diseases and disabilities affect the use of assistive technologies (e.g., [33, 34]) and investigated why a high proportion of available technologies are rejected. Frequently, these analyses (focusing on technology acceptance of diseased or disabled people) remain on a theoretical basis and are in parts unspecific and superficial as they did not integrate disabled people. This is precisely where research is required:

disabled people have to be integrated in the design process of assistive technologies and the care-relevant user factors age, diseases, and disabilities should be focused.

To understand requirements and perceptions of disabled people in need of care, it is also important and useful to integrate and consider the perspectives of professional and family caregivers. So far, some studies [35, 36] have examined the requirements and professional and family caregivers' perspectives on AAL systems and technologies separately. Another study focused on future users (caregivers and patients) and their perceived concerns related to in-home monitoring technologies [37]. On the one hand, these studies enable first insights into diverse user perspectives on the acceptance of assistive smart home and AAL technologies. On the other hand, they do not allow a direct comparison of the perspectives of "affected people" (older, diseased, or disabled people) with family or professional caregivers compared to "not-experienced" people. Summarizing, there is sparse knowledge about the acceptance of smart home and AAL technologies regarding disabled people and people with special care needs as well as other care-relevant user factors. This is especially true for the perspectives of user groups with different experience and domain knowledge - disabled people, their relatives and family members as well as professional caregivers. For this reason, the current study focuses on the acceptance of assistive smart home technology systems with regard to people having different experiences with disabilities and resulting care needs.

## 3 Capturing Motives and Perceptions: Qualitative Insights

We choose a multi-method approach for our study consisting of a qualitative interview study and a consecutive quantitative questionnaire study. In this section, the research design is presented starting with a description of the qualitative interview study, which was taken as a basis for the subsequent quantitative study. Our approach addressed three essential research questions:

1. How do the participants evaluate a smart home technology system and which perceived benefits and barriers are most relevant for its acceptance?
2. To which extent does experience with disabilities influence the system's evaluation and the perception of benefits and barriers?
3. How are the relationships between perceived benefits, perceived barriers, trade-offs, acceptance, and experiences with disabilities (as user factor)?

As it was detailed in Sect. 2, previous research on the acceptance of AAL technologies was mostly focused on older users. In contrast, there is only sparse knowledge about developing AAL technologies for people with disabilities and also rarely research on the acceptance of AAL technologies focusing on users with different experiences regarding disabilities. Those diverse perspectives (e.g., professional caregivers, relatives and families of disabled people) are also of prime importance as they can support and complete the understanding of potential disabled user's needs and wishes. Hence, a qualitative interview study was initially necessary to identify perceived usage motives and barriers of usage. Only on this basis, it was reasonable to design and conduct a quantitative study focusing on people having different experiences with disabilities and resulting car needs (themselves, families and relatives, professional caregivers).

### 3.1 Methodology and Design

The methodology of guided interviews was chosen for the preceding qualitative study. Interviews in this sensible topic enable direct and personal contact to the participants, reach a more personal level, and ensure detailed discussions about personal topics. The interviews should provide insights into the desires, perceptions, and requirements of disabled people and people in need of care.

The interview guideline was structured in different parts. After introducing the topic and interview process, the participants were asked for demographic aspects as well as for personal information with regard to disabilities (e.g., own experiences; type, duration and symptoms of the disability). Afterwards, the participants were asked for some information concerning their living circumstances (i.e., housing situations, daily routine, incidental problems in everyday life).

Subsequently, a smart home technology scenario was read to the participants in order to show them a possible technical solution quite plainly that has the potential to facilitate their life. The scenario was used to create a basis for evaluation with regard to all interview participants and was designed as a very personal everyday situation. The participants should close their eyes while listen to the scenario and imagine that the scenario took place at their own living environment. Within the scenario, the implemented smart home technologies were not visible and enabled especially automatic lighting control (by light sensors and motion detectors), a hands-free kit for communication (by microphone, video-camera, and monitor), automatic control of doors and windows (by sensors and motion detectors), and memory functions (e.g., for drugs or measurement of medical parameters via smartphone).

Following the scenario, the participants were asked for their opinions on the described system as well as their ideas with regard to potential benefits and barriers. In the next part, the participants were explicitly consulted to indicate which motives and barriers were crucial for them and under which conditions they would use the smart home system. Specifically, the trade-off between increasing autonomy and independency on the one hand, and protecting own privacy and data security on the other hand has been focused. Finally, the participants had the opportunity to make previously not-mentioned, but for them personally important aspects a subject of discussion.

The guideline enabled that the conducted interviews were comparable, all relevant topics were mentioned and discussed, and all relevant questions were asked. Still, at any time, the participants could add questions, topics, and aspects, which were relevant from their point of view.

The interviews were recorded and protocols with relevant information (date, time, and place of interview, demographic information of participants) were prepared. Afterwards, the interviews were transcribed and anonymized. The interview's results were analyzed by qualitative content analysis [38].

### 3.2 Participants

As interview partners, we searched for participants who are disabled or in need of care themselves, relatives of disabled people in need of care, or professional caregivers of

people with disabilities and care needs. The participants were recruited by personal contact and via email to reach associations and advice institutions regarding disabilities and care needs.

Nine participants (n = 9) were chosen and took part in the interviews that lasted between 40 and 70 min. Three participants were female (male: n = 6) and the participants were between 26 and 62 years old (M = 35.6). Seven interviewees indicated to have disabilities (n = 7) (e.g., infantile cerebral palsy, arthrogryposis multiplex congenita). Three disabled participants indicated to require support and assistance by an outpatient nursing service as well as support by a domestic help. Two participants made use of assisted living facilities, while in each case one participant lived in a stationary care institution and one participant needed currently no assistance in his everyday life.

Further, a relative of two disabled children (n = 1) and a professional caregiver (n = 1) took part in the study, who had both experiences with a broad range of disabilities.

### 3.3 Key Results

As the qualitative study served as a basis for the subsequent questionnaire study, the qualitative results were presented that are relevant for the subsequently presented quantitative results (i.e., perceived motives and barriers concerning the smart home technology system).

**Potential Usage Motives.** Eleven usage motives were identified during analysis. *Expansion of autonomy* represented an important motive for all participants as it is of great relevance for disabled people to are able to carry out everyday tasks autonomously. Closely related to this, the motive *to reduce dependency from others* was focused. Here, a participant (male, 32) took the example that he not wants to depend on others "keeping entrance doors open" for him as he perceives it as a kind of paternalism. Along with this, almost all disabled participants considered *compensation of mobility constraints* as important usage motive of a smart home technology system.

*Facilitating everyday life* was another important usage motive and the participants mentioned support for standing up and control of household appliances as examples. Most of the participants also focused on the motive *increase the feeling of safety* by using a smart home technology system, e.g., "…then you are able to look who is standing in front of your entrance door…" (female, 27). As further usage motive some participants mentioned *the relief of caring family, relatives and professional caregivers*: for example, disabled participants expressed that they don't want to ask their caregivers for minor details (e.g., "control of music" (male, 31)).

Two participants considered *time savings* as additional benefits by using a smart home system (e.g., tasks in household, automatic opening and closing of doors). One participant mentioned *comfort* as usage motive while it was not relevant for the other participants as they want to be supported only in the respective areas where they otherwise would need human assistance. Further, one participant mentioned that by using technologies the *confrontation with own care needs could be reduced*. *Staying longer at the own home* was mentioned as usage motive by the professional caregiver as he had the experience with some older people who could stay at their own home by

means of using specific assistive technologies. Finally, the interviews illustrated that disabled people are in frequent contact with medical doctors and ministries: here, the exchange and access of data is very time-consuming as well as problematic and two participants assumed that an implemented system enables *a fast data access*.

**Potential Usage Barriers.** As one of the most relevant usage barriers *isolation due to the substitution of care staff by technologies* was mentioned especially by the relative and professional caregiver of disabled persons. In contrast, the disabled participants discussed this aspect controversially: e.g., "I would clearly prefer it if a robot would assist me on the toilet than care staff" (male, 33).

The usage barrier *feeling of surveillance* was discussed contrarily too: most of the participants criticized the feeling of surveillance and perceived the technology partly as an invasion in their own privacy, while a participant negated the feeling of surveillance and argued that "smartphones already collect lots of information" (male, 33).

As further potential usage barrier, some participants feared a *too large proportion of technology in their everyday life*. Along with this, it was crucial that the applied technology is functional and hence, *functional incapacity* of technologies and systems – not surprisingly – represented a central usage barriers. Accompanying, the applied system should be easy to operate and control; therefore, *the expectation of a too complicated handling* of the system also represented a usage barrier. Further, some participants mentioned concerns regarding transmission of false information, e.g., falls alarms.

Two participants mentioned a potential usage barrier if *more time is spent on technology usage compared to human assistance (no effective time savings)*. In almost all interviews it was mentioned that the system was perceived as useful if they are needed:

> "… as I can do most everyday tasks on own, I would currently decide against the system. However, I really like the opportunity to have it" (female, 37).

Along with this aspect, the interviews revealed that some people's *care needs are that intensive* that smart home technology are *not relevant and usefully applicable:*

> "The system does not substitute complete assistance – if I am not able to take a shower myself, then the system will not support me to do it" (female, 37).

The results concerning usage motives and barriers align with previous research concerning several aspects (e.g., comfort, facilitating everyday life (e.g., [39]). However, the results are multifaceted and go beyond previous findings due to the reference to disabilities and constraints (e.g., compensation, reduce confrontation with care needs, to be afraid of isolation). Hence, these aspects must be examined quantitatively to be able to do justice to diverse user groups and their different experiences with disabilities and care needs.

**Perception of Assistive Smart Home Technologies.** To get insights into the participants' perceptions and attitudes towards the described system, the participants were asked to describe their opinions using three associating words following the read scenario. Analyzing the used words, differences between the participants were striking: the relative and the caregiver predominantly used negative and critical words to describe their perceptions of the scenario such as *lonely, unhuman, heteronomous,* and

*violation of personal rights and privacy.* In contrast, the disabled participants used more positive and fascinated words to describe their feelings and opinions. The most associated words were *exciting, facilitation, useful, helpful*, and *comfortable*. These results showed that a differentiation between the perspectives involved in caring situations is indispensable.

### 3.4 Conclusions for Quantitative Study

Within the individual interviews, we reached conversations on a very personal level with each interview partner and thus, spontaneous, individual and open answers were enabled. Regarding potential motives and usage barriers, 20 categories were defined and the participants' general attitude towards the introduced system was analyzed. The interviews gave an impression of how complex the issues "care" and "disabilities" are and how diverse the evaluation of assistive technologies can be if different user groups were considered. Even though the participants had different priorities in the interviews, we noticed, that all disabled participants expressed a distinctive wish towards independency and autonomy: it was very important for them not to become too conveniently and to be supported only in the respective areas where it is necessary. Most the participants emphasized the importance that disabled people or people in need of care should decide on their own if, and if so which technology is used.

The presented qualitative results served as a basis for the conception of the quantitative questionnaire. Additionally, the answers collected were used to create items regarding the trade-off between potential usage motives and barriers. Furthermore, the qualitative results confirmed that it is important and necessary to integrate people with different experiences concerning disabilities and needs for care and assistance into the follow-up quantitative study and future studies as well.

## 4 Quantifying Motives and Acceptance: Questionnaire Study

To quantify the previously gained qualitative results, an online questionnaire study was conducted focusing on people having different experiences with disabilities and care needs. Within this section, the methodological design, the sample, and the quantitative results are presented.

### 4.1 Methodological Questionnaire Design

Based on the findings of the previous interview study, we developed our online questionnaire consisting of different parts. The first part addressed demographic aspects, such as age, gender, educational level, and income. In the following part, the participants were asked for their experiences with disabilities by indicating (a) if themselves are disabled (b) if they are related to a disabled person, (c) if they are the caregiver of a disabled person, or (d) if they have no experiences with disabilities. Afterwards, the participants were asked to indicate, whether and to which extent (care time, type of care, intensity of care) themselves (a, d) or the person they put themselves in position with (b, c) needs care. As detailed attitudinal information, the participants

evaluated several items concerning their needs for data security and privacy. Needs for data security were evaluated using 14 items ($\alpha$ = .87), while needs for privacy were assessed using eight items ($\alpha$ = .72).

A scenario was designed in order to ensure that all participants pertain to the same baseline regarding the evaluation of the smart home technology system. The scenario was conceptualized telling a very personal everyday situation wherein the participants should imagine that an specific, invisible smart home technology system was integrated in their home environment and contained the following functions: setting of the home temperature using the smartphone, automatic control of light control using light sensors and position localization, a hands-free kit for phoning enabled by integrated microphones, automatic opening and closing of (front) doors and windows via integrated sensors, monitoring of front door area by video camera, and fall detection by integrated sensors in floor and bed.

Depending on their background (need of care, experience with disabilities), the participants were introduced to the scenario differently. For cases b, c, and d, the participants were asked to put themselves in the/a disabled person's position (more specifically the person they are related with or they care (b + c)) while answering the questions concerning the smart home system scenario. Participants who indicated to be not in need of care were asked to imagine that they would need care during the scenario.

Afterwards, the participants evaluated perceived usage motives (11 items) of the system (e.g., to increase autonomy, to reduce dependency on others, to facilitate everyday life, to relieve fellow people) and perceived barriers of usage (9 items) (e.g., feeling of surveillance, no trust in functionality, to assume a too difficult usage, to be afraid of isolation) based on the findings of the qualitative interview study (see Sect. 3.2; all items are illustrated in Fig. 2). Additionally, the participants evaluated two trade-offs between perceived benefits and barriers: (a) autonomy and independency are more important than data security (three items; $\alpha$ = .84) and (b) data security and privacy are more important than the usage of smart home and AAL technologies (three items; $\alpha$ = .71). In the following part, the participants should assess the acceptance or rejection of the described system (by evaluating eight items, Fig. 1) including the behavioral intention to use such a smart home technology system. All items had to be answered on six-point Likert scales (1 = min: "I strongly disagree"; 6 = max: "I strongly agree").

Finally, the participants had the opportunity to reason their opinions towards the described system on an optional basis and to provide their feedback concerning the questionnaire and the topic itself. For completing the questionnaire, the participants took on average 15 min. Data was collected in an online survey in Germany (available for 6 weeks) in summer 2016.

### 4.2 Sample Description

182 participants volunteered to take part (acquired by personal contact and distributed online in social network forums). The participants were on average 38.7 years old (SD = 13.95; min = 20; max = 81), 62.1% of the sample were female, 36.3% were male, and 1.6% gave no answer asked for gender. Overall, the sample was highly educated with 46.7% holding an university degree and 14.8% an university entrance diploma.

Asked for their experience with disabilities, 28% of the participants indicated to be disabled (n = 51), 12.1% (n = 22) were professional caregivers, and 19.2% participants were relatives of a disabled person (n = 35). As a control group, we also integrated people without experiences regarding care and assistance needs caused by disabilities (40.7% (n = 74) of the participants were not-experienced). Concerning current needs of assistance and care, 43.4% (n = 79) participants indicated to need care or that the person - they put themselves in position with (see Sect. 4.1) - needed care (56.6% (n = 103) were not in need of care).

Correlation analysis revealed that the user factors were related only partially: not surprisingly, experience with disabilities correlated with current care needs ($r = .607$; $p = .000 < .05$). Age was not related with experience with disabilities ($r = -.132$; $p = .075 > .05$) nor with current care needs ($r = -.096$; $p = .197 > .05$). Instead, age was related with gender ($r = .200$; $p = .007 < .05$; 1 = female; 2 = male).

Further, the participants reported to have on average a positive technical self-efficacy (M = 4.5; SD = 1.0; min = 1; max = 6) and a slightly positive attitude towards technology innovations (M = 3.9; SD = 1.0; min = 1; max = 6). Additionally, they indicated their needs for data security (M = 4.1; SD = 0.8; min = 1; max = 6) and privacy (M = 4.4; SD = 0.7; min = 1; max = 6), which both were on average positive.

### 4.3 Detailed Group Description (Experience with Disabilities and Care Needs)

To understand the diversity of the user groups under study, their previous experiences, as well as their requirements and needs referring to care and assistance are presented in this section separately for each user group.

**Disabled Participants (n = 51).** Most of the participants with disabilities provided corresponding information about the type of their disability (n = 44): paralyses (in different extent) were mentioned very frequently (n = 17) (e.g., paraplegia, hemiplegia), followed by disabilities caused by muscle diseases (n = 9) (e.g., muscular atrophy, muscular dystrophy) and neurological diseases (n = 7) (e.g., multiple sclerosis, Parkinson's disease). Further, disabilities in terms of missing extremities (i.e. legs) (n = 2) and other walking impediments (n = 9) (e.g., dwarfism, contracture) were mentioned. Nearly half of the participants reported to be disabled by birth (47.1%), the other participants reported to suffer from their disability a long time ago (in years: M = 25.3; SD = 18.3; min = 3; max = 64). Two thirds of the participants reported to be constantly in need of care (66.7%, n = 34). Most of them indicated to be assisted by their families/partners in combination with professional care staff (n = 15) or only by families/partners (n = 12), whereas few participants were assisted only by professional care staff (n = 3). N = 23 participants reported to need assistance in the areas body care, mobility, housekeeping, and nutrition, while only two participants needed assistance in two of these areas (n = 9 in three areas).

**Relatives of Disabled People (n = 35).** Asked for the living circumstances of their disabled relative, the majority (67.6%) reported that he/she lived together with the family, while each 8.1% live alone, with partner, or in a flat-sharing community. More than half (54.3%) of the participants indicated that their relatives are disabled by birth.

82.9% of the participants (n = 29) reported that their relatives are constantly in need of care, while the daily time for care was on average 7.4 h (SD = 6.8; min = 1; max = 24). The majority of the disabled relatives in need of care is cared by their families and partners (n = 15) or by professional care staff and their families/partners (n = 11). In contrast, few participants were cared only by care staff (n = 3). Further, most of the disabled relatives in need of care (n = 19) needed assistance in the following four areas: body care, mobility, housekeeping, and nutrition. All of them (n = 29) needed assistance in at least two of the mentioned areas.

**Professional Caregivers (n = 22).** Asked for the living circumstances of the people the professional caregiver group maintained, they reported that 40.9% live in stationary care facilities, 27.3% live with their family, 13.6% live alone, and each 9.1% in a flat-sharing community and in assisted living. Further, they indicated that the majority (81.8%) was constantly in need of care. In contrast to the group of disabled participants who indicated to be physically disabled, the professional caregivers maintained people with physical and mental disabilities (e.g., trisomy 21, autism). Almost all of these people needed assistance in the areas body care, mobility, housekeeping, and nutrition.

**Participants with No Personal Experience Regarding Disabilities (n = 71).** 43.2% indicated to live together with their partner, 24.3% live together with their family, 17.6% live alone, and 14.9% live in a flat-sharing community. Not surprisingly, none of the not-experienced participants indicated to need care.

### 4.4 Key Results

First, the results were analyzed descriptively, followed by linear regression analyses and by (M)ANOVA procedures to investigate potential effects of user diversity (level of significance was set at 5%). Independent variable was the experience with disabilities to analyze the influence of assistance and care needs on perceived benefits, barriers, and acceptance as dependent variable. The results section starts with the description of the findings for acceptance of AAL, perceived benefits, and perceived barriers referring to the whole sample. Then, influences of user-specific characteristics on perceived benefits and barriers as well as acceptance of smart home technologies are reported [40]. Finally, the relationships between the perception of benefits and barriers and smart home technology acceptance are focused, modelled, and complemented by effects of user diversity.

**General Acceptance of AAL.** Aprior study [40] focused on acceptance of smart home and AAL technologies, which was on average positively evaluated (M = 4.6; SD = 1.0).

Zooming into the evaluation of the respective items (Fig. 1), the participants' highest agreement was found for items referring to care needs (*...due to care needs* (M = 4.7; SD = 1.1) and ... *reduce my care needs* (M = 4.5; SD = 1.3)). In comparison, items with regard to the intention to use an AAL system were rated less positive (e.g., *I can imagine using AAL technologies now* (M = 3.8; SD = 1.6)). The participants rejected all items that militate against usage similarly (e.g., *I think AAL technologies are superfluous* (M = 1.9; SD = 1.1)).

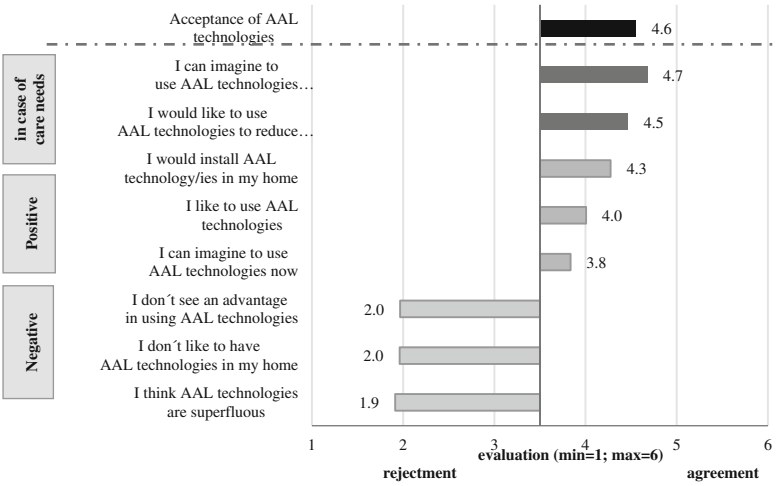


**Fig. 1.** Evaluation of AAL system acceptance [40].

Figure 2 (left) shows the results of the evaluation of perceived benefits of the AAL system. Apparently, all items were perceived as benefits (above the scale's mean).

The benefit *to facilitate everyday life* (M = 5.2; SD = 0.9) was evaluated highest, followed by *to expand own autonomy* (M = 5.2; SD = 1.0), *to extend staying at home* (M = 5.1; SD = 1.0), and *to reduce dependency from other people* (M = 5.1; SD = 1.0). The items *to relieve fellow people* (M = 4.9; SD = 1.1), *to compensate reduced mobility* (M = 4.8; SD = 1.0), *comfort* (M = 4.7; SD = 1.2), and *to increase the feeling of safety* (M = 4.6; SD = 1.3) were lesser important. *Time savings* (M = 4.3; SD = 1.4), *to enable fast data access* (M = 4.0; SD = 1.4), and *to reduce own conflict with care needs* (M = 3.9; SD = 1.4) were comparably minor important.

To understand which items are most relevant for the decision to use AAL systems, we conducted a stepwise linear regression analysis with all perceived benefit items as independent and the acceptance sum score as dependent variable. The results revealed two significant models for the whole sample. The first model predicted 27.2% (adj. $r^2 = .272$) variance of acceptance and was premised on the benefit *to expand own autonomy* ($\beta = 0.525$; $t = 8.279$; $p < .000$). Hence, *to expand own autonomy* was the most important benefit for the acceptance. The second model explained 29.2% (adj. $r^2 = .292$). Beyond the already identified factors, additionally the item *time savings* was included. Therefore, *time savings* ($\beta = 0.166$; $t = 2.459$; $p < .05$) and *to expand the autonomy* ($\beta = 0.462$; $t = 6.823$; $p < .000$) were the most important benefits and influenced the acceptance of the described system.

Figure 2 (right) illustrates the evaluation of perceived barriers of the system. In contrast to the perceived benefits, none of the items was perceived as "real" barrier - as all values were below the mean of the scale. Zooming into the items' evaluation, the participants perceived the system not as *superfluous* (M = 1.9; SD = 1.0) or *irrelevant* (M = 2.4; SD = 1.1). They judged the *usage not to be too difficult* (M = 2.6; SD = 1.2) and rejected *to have no trust in the functionality* (M = 2.8; SD = 1.3). The items

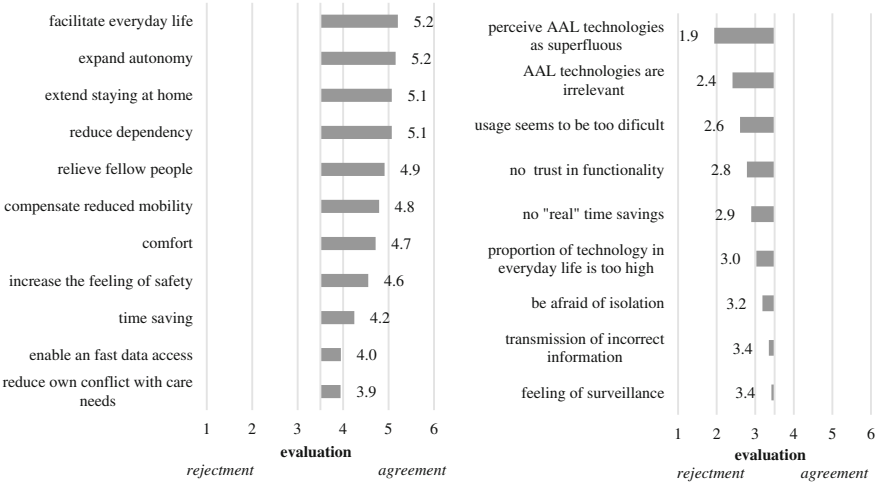


**Fig. 2.** Evaluation of perceived BENEFITS (left) and BARRIERS (right) regarding the described AAL system scenario [40].

*proportion of technology in everyday life is too high* (M = 3.0; SD = 1.5) and *to expect to have no "real" time savings* (M = 2.9; SD = 1.2) were slightly rejected by the participants. This was also true for the item *to be afraid of isolation* (M = 3.2; SD = 1.5). In comparison, *transmission of incorrect information* (M = 3.4; SD = 1.3) and *feeling of surveillance* (M = 3.4; SD = 1.5) were rated rather neutrally, thus, these two items were the most likely barriers.

After descriptive analyses, a stepwise linear regression analysis was also conducted in order to figure out which barriers influenced the acceptance of the system the most. For this purpose, perceived barriers were integrated as independent and the acceptance sum score as dependent variable into the analysis. The results revealed three significant models for the whole sample. The first model predicted 35.1% acceptance variance (adj. $r^2 = .351$) premised on the barrier *AAL technologies are irrelevant* ($\beta = -0.596$; $t = -9.945$; $p < .000$). Apparently, participants accept the AAL system only if it is really needed and that they want to do as much as possible autonomously on their own. The second model explained 41.7% (adj. $r^2 = .417$) and contained additionally the barrier *proportion of technology in everyday life is too high* ($\beta = -0.285$; $t = -4.624$; $p < .000$) (*irrelevant* ($\beta = -0.484$; $t = -7.850$; $p < .000$)). Ultimately, the final model explained 42.9% (adj. $r^2 = .429$) and was premised on the factors *to be afraid of isolation* ($\beta = -.139$; $t = -2.151$; $p < .000$), *proportion of technology in everyday life is too high* ($\beta = -0.235$; $t = -3.591$; $p < .000$), and *AAL technologies are irrelevant* ($\beta = -0.453$; $t = -7.228$; $p < .000$). As the analyses of acceptance, benefits, and barriers regarded the whole group so far, it was of importance to investigate whether these factors differ even more regarding diverse user groups. Additionally, it was important to analyze whether and to which extent the system's acceptance differed depending on users with different needs for assistance and care.

**User-Specific Characteristics.** For this analysis, the factor experiences with disabilities was integrated as independent variable to analyze the influence of living with disabilities on the acceptance, perception and evaluation of AAL systems.

*User-Specific Acceptance of AAL Systems.* The MANOVA analyses showed a significant influence of experiences with disabilities ($F(24,465) = 2.060$; $p < .01$) on the acceptance of the described smart home system. This influence occurred for all respective items and is illustrated in Fig. 3.

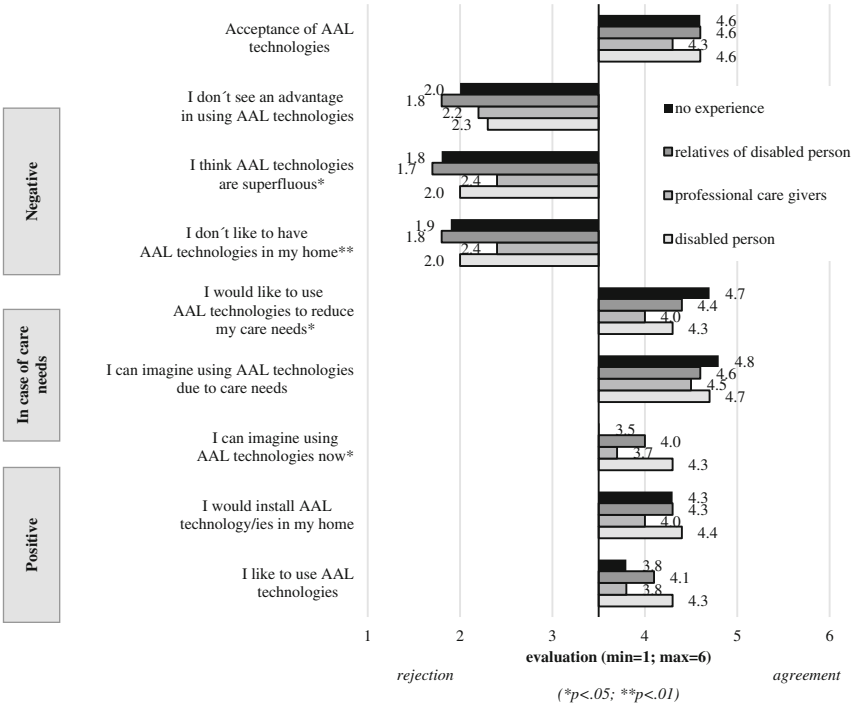


**Fig. 3.** Evaluation of acceptance depending on the user factor experience with disabilities [40].

The sum-score *acceptance of AAL technologies* was rated rather similar, except for the professional caregivers who showed comparatively the lowest acceptance scores ($F(3,162) = 2.646$; $p < .1$). With regard to two of the negative statements (…*superfluous* $F(3,162) = 2.895$; $p < .05$) and … *don´t like to have AAL technologies in the own home* $F(3,162) = 4.907$; $p < .01$), the professional caregivers showed the lowest rejection. This showed, that they in tendency possessed a higher negative attitude towards the described system than the other three user groups. This evaluation picture occurred again for the item *the intention to use AAL technologies to reduce care needs* ($F(3,162) = 2.981$; $p < .05$): the disabled participants, relatives of disabled people, and not-experienced participants showed a clearly higher agreement, while the professional caregivers showed the lowest acceptance scores. Interestingly, the group of

not-experienced participants showed the highest agreement referring to the two *"in case of care needs"*-statements. This evaluation pattern changed regarding the more concrete intention to use item *I can imagine using AAL technologies now*, which was clearly lower agreed by the not-experienced participants (M = 3.5; SD = 1.7) compared to the group of disabled people (M = 4.3; SD = 1.3; $p < .05$, post-hoc-tests: Tukey's HSD).

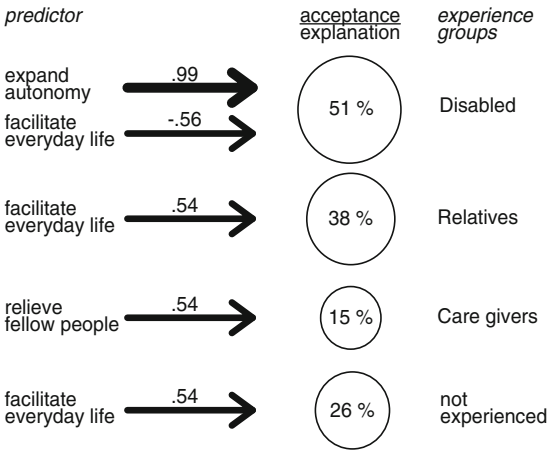


**Fig. 4.** Results of regression analysis – benefits & acceptance for experience with disabilities groups [40].

*User-Specific Evaluation of AAL Benefits.* MANOVA analyses revealed no significant omnibus effect of experiences with disabilities on the evaluation of benefits. In contrast, some of the single benefit items were rated significantly different depending on the user factor experience with disabilities. In a next step, we conducted a stepwise linear regression analysis to investigate which benefits are most important and acceptance-relevant for which user group and acceptance-relevant for which user group. The results of the regression analysis referring to the experience with disabilities user groups are illustrated in Fig. 4.

The final regression model for the group of disabled participants predicted 50.5% (adj. $r^2 = .505$) of the system's acceptance and was based on the benefits *to expand autonomy* ($\beta = .985$) and *to facilitate everyday life* ($\beta = -.564$). For the group of relatives of disabled people the model explained 37.5% of variance (adj. $r^2 = .375$; $\beta = .535$) and for the not experienced group 25.5% (adj. $r^2 = .255$; $\beta = .633$) - in each case based on the benefit *to facilitate everyday life*. For the professional caregivers, the final regression model explained only 15.4% (adj. $r^2 = .154$) of acceptance variance and was premised by the benefit *to relieve fellow people* ($\beta = .399$).

*User-Specific Evaluation of AAL Barriers.* The same procedure was conducted for the perceived barriers as previous MANOVA analyses revealed only a slight significant omnibus effect of experiences with diseases ($F(27,468) = 1.502$; $p < .1$) and again

single barriers were rated significantly different. The results of the final linear regression analyses for all experiences with disabilities groups are illustrated in Fig. 5.

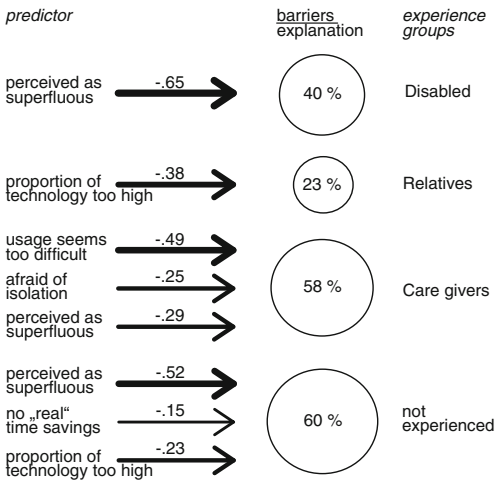


**Fig. 5.** Results of regression analysis – barriers & acceptance for experience with disabilities groups [40].

For the groups of relatives, the model predicted only 23.1% of variance of acceptance (adj. $r^2 = .231$) and with the barrier *the proportion of technology in everyday life is too high* ($\beta = -.376$). For the group of disabled participants, the model explained 39.9% of AAL acceptance variance (adj. $r^2 = .399$) premised on the barrier *to perceive AAL technologies as superfluous* ($\beta = -.649$). With regard to the group of professional caregivers, the final model predicted 58.3% (adj. $r^2 = .583$) of variance and was affected by the barriers) *to perceive AAL technologies as superfluous* ($\beta = -.293$), *usage seems to be too difficult* ($\beta = -.494$), and *to be afraid of isolation* ($\beta = -.249$). Finally, and referring to the not-experienced group, the final model explained 60.2% of AAL acceptance variance based on the three barriers *to expect no "real" time savings* ($\beta = -.154$), *to perceive AAL technologies as superfluous* ($\beta = -.520$), and the concerns that *the proportion of technology in everyday life is too high* ($\beta = -.227$).

### 4.5 Acceptance Model Relationships

In order to figure out how perceived benefits, barriers, and trade-offs between them are related with the acceptance of smart home technology systems, correlation analyses were calculated (see Fig. 6). The results showed that *perceived benefits* ($r = .497$; $p < .01$) and *perceived barriers* ($r = -590$; $p < .01$) were directly related with the acceptance of the described system. Further, the integrated constructs dealing with trade-offs between benefits and barriers were both related with acceptance: the tradeoff that *autonomy and independency as benefits are more important than data security*

*(TO1)* was related with acceptance (r = .438; p < .01) and - not surprisingly - with perceived benefits (r = .486; p < .01). Further, the trade-off that *data security and privacy are more important than the usage of smart home and AAL technology systems (TO2)* was negatively related with acceptance (r = −.374) and – also not surprisingly – with perceived benefits (r = .471; p < .01).

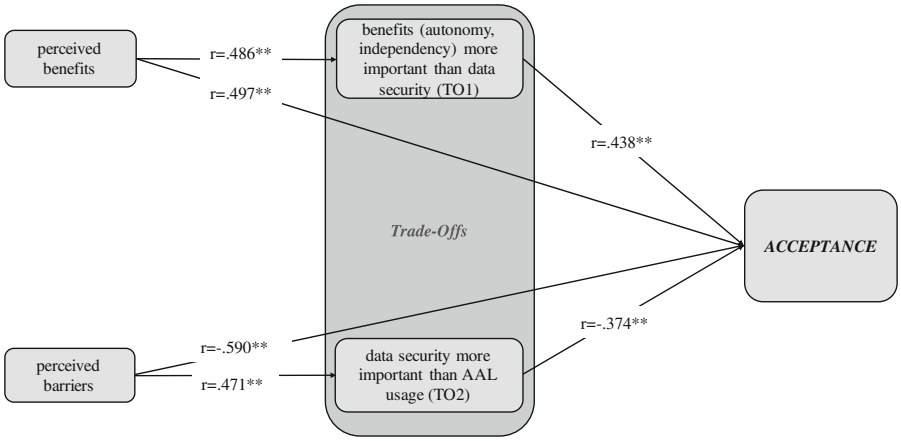


**Fig. 6.** Model of relationships between perceived benefits, perceived barriers, and AAL acceptance.

In a second step, we also included user diversity as well as attitudinal variables into the analysis. Figure 7 illustrates the relationships between perceived benefits, barriers, their trade-offs, and acceptance including user and attitudinal factors.

The grey arrows show that the attitudinal variables *need for privacy* and *need for safety* were significantly related with the previously described acceptance model. Correlation analyses revealed that the needs for data security were related with the perception of barriers (r = .344; p < .01), however only marginally with the perception of benefits (r = −.160; p < .1). Further, needs for data security were linked to both tradeoffs TO1 (r = −.435; p < .01) and TO2 (r = .488; p < .01) as well as to acceptance (r = .−310; p < .01). Similarly, needs for privacy were related to perceived barriers (r = .238; p < .01) as well as tradeoffs TO1 (r = −.339; p < .01) and TO2 (r = .460; p < .01).

The black arrows illustrate the influence of experience with disabilities within the acceptance model. This factor significantly influenced the perception of barriers (not the perception of benefits) as well as the acceptance of the described system. Interestingly, experience with disabilities was also linked to the evaluation of trade-offs *autonomy and independency as benefits are more important than data security (TO1)* (F(3,178) = 2.995; p < .05) and *data security and privacy are more important than the usage of smart home and AAL technology systems (TO2)* (F(3,178) = 3.968).

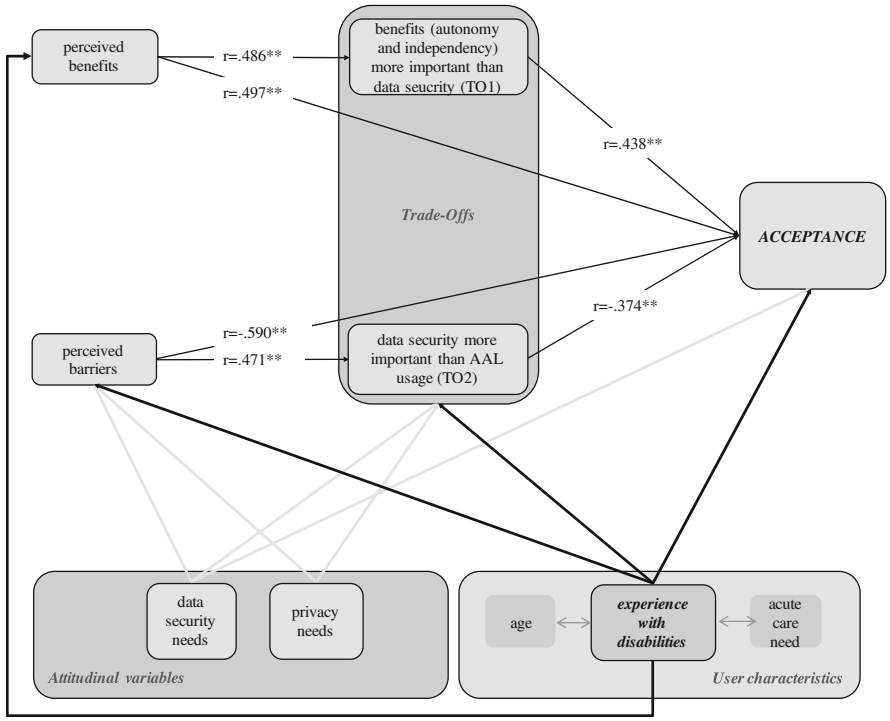


**Fig. 7.** Model of relationships between benefits, barriers, and acceptance complemented by the influence of user diversity factors.

## 5 Discussion

Sections 5.1, 5.2, and 5.3 provide discussions of the previously presented research results as well as answers to the study's underlying research questions (see Sect. 3.1). Further, limitations and an outlook for future research in the field are presented (Sect. 5.4).

### 5.1 Decisive Perceived Benefits and Barriers for Smart Home Acceptance

In accordance with previous research results [22], our results show that a holistic smart home and AAL system with a wide spectrum of functions is overall accepted and rated positive by all user groups. Referring to the context of care needs, the intention to use the system is present and differs only slightly regarding the different user groups. Whenever potential care needs are subject of discussion in an intention-to-use-context, they are more important than other wishes or concerns and the AAL system would be used in this regard.

Overall and referring to the whole participant group, the acceptance was more predicted and explained by perceived barriers than by perceived benefits. The results of the regression analyses for all participants reveal that *expanding the autonomy* was the

beneficial factor with the biggest influence on acceptance followed by *time savings*. Concerning perceived barriers, *to be afraid of isolation*, *proportion of technology in everyday life is too high*, and *AAL technologies are irrelevant* were the most acceptance-relevant criteria. In parts, these results are in line with previous research [39, 41], in which especially older participants were afraid of the proportion of technology and a potential isolation in consequence of technology usage. As mentioned before, these new results in the context of experience with disabilities and resulting care needs should be addressed and deepened in future studies. Interestingly, the evaluation of perceived benefits and barriers as influencing factors for the acceptance of smart home systems strongly depends on experience with disabilities and care (see Sect. 5.2).

## 5.2 The Perspective of Experience with Disabilities

Although the system was overall accepted and evaluated positive by all user groups (see Sects. 4.4 and 5.1), some significant differences between the groups are striking and are illuminated in this section.

If it was asked for the intention to use the system without mentioning the context of care needs, significant differences between the user groups become obvious: in tendency - disabled people and people in need of care indicate a clearly higher acceptance (intention to like to use an AAL system currently or to install an AAL system in their home environment) compared to healthy people without personal experiences with disabilities or care needs. Thus, the fact that people are concerned with health issues and care needs influences the AAL system acceptance. This is a common research finding regarding age as previous research revealed that older participants show higher acceptance scores of assisting technologies than younger people [41]. However, this is a comparatively new phenomenon concerning diseases and disabilities. Focusing on different experiences with disabilities, the evaluations of the professional caregivers group are striking as they indicated to have a more negative attitude towards AAL systems in comparison with all other groups [42]. Particularly, this was obvious during the statements in the interview studies, in which the professional caregivers described AAL systems in parts as spooky, impersonal, or inhuman. Due to previous research findings and current studies, we assume that professional care staff takes a more critical attitude than other user groups due to concerns about a difficult handling of the technology, concerns to be replaced by technology, and also due to a lower general trust in technology. Hence, future studies should focus especially on professional caregivers and analyze their requirements and wishes to be able to integrate them into the development of smart home and AAL technologies and finally, to increase their openness and acceptance of such technologies in professional care contexts.

The evaluation of motives to use and perceived barriers not to use an AAL system differed also regarding user diversity. As a first aspect, it is striking for the group of disabled participants, that the main perceived benefits carry greater weight than the perceived barriers (see Sect. 4.4). The disabled participants of our study associate the in the scenario described AAL system as helpful, very useful, and comfortable. It is most important for them that the applied technical system helps to *expand their autonomy*. In contrast, *facilitation of everyday life* is a comparatively incidental or even not desired benefit as most people of this group want to cope with as much everyday tasks as

possible on their own. Hence, smart home and AAL technology systems could be very enriching for disabled people as they have the potential to help those people to help themselves. In contrast, the most important barrier for this participant group represents the aspect that the use of technology is *seen as superfluous.* As this refers to the concern that the technology undertakes tasks the people would like to do autonomously, it represents the most important benefit's counterpart and highlights the importance of autonomy for this specific user group.

Referring to the perspective of relatives of disabled people, their acceptance results can be best compared with the disabled people's perspective: for them, also the perceived benefits are in tendency more important than the perceived barriers. However, this is not true for the most important usage motives: in line with previous results [39] (but in contrast to the results of the disabled participants group), for the not experienced group, the relatives, and the professional caregivers groups, the benefits *facilitation of everyday life* and *relief of fellow people* are the key motives to use AAL systems.

Focusing the not experienced and the professional caregivers group, the perceived barriers carry clearly more weight than the perceived benefits of smart home and AAL systems. This fits the results of the qualitative study, in which the professional caregivers described the system primarily as spooky and undesirable (see Sect. 3.3). However, there are also differences between these two groups as they weight the perceived barriers differently. For the professional caregiver group, concerns about a difficult usage of the technology is relevant. We assume that this is due to concerns that the workflow is affected and slowed down by technical and especially handling difficulties. In contrast, doubts about a too high proportion of technology and if the technology is really necessary are relevant barriers for the not-experienced group.

Summarizing, this study's results show that the acceptance of smart home and AAL systems depends on the user factor experience with disabilities and resulting care needs. Besides acceptance, the motives for use or non-use of the described system differ with respect to user diversity. Based on the presented results, we suggest including disabled people into early development stages of smart home and AAL technologies to reach technical solutions that are personalized and sufficiently adapted to individual requirements. Equally, professional care staff should be integrated in future studies as they present the most critical users. Thus, not only facilitating and management of everyday life can be ensured at home but also at professional care environments and contexts.

### 5.3 A Holistic View: Relationships Between Benefits, Barriers, and Trade-Offs

Although the presented model shows that perceived barriers influence the acceptance more strongly than perceived barriers, the direct trade-offs between them are predominantly evaluated in favor of the benefits and system usage. The weightings and trade-offs between perceived benefits and perceived barriers clarify the importance to conceptualize respective communication and information strategies thoroughly. By providing easily comprehensible information about the usage of the system, the data handling, technical characteristics as well as the potential applications of the system, concerns and fears could at least be reduced.

The model as well as Sect. 5.2 also illustrate that user diversity clearly shapes smart home and AAL system acceptance. Besides experience with disabilities, especially needs for privacy and data security present factors that are extremely relevant for acceptance as well as for the perception of benefits and barriers within the present study. This is detailed in another study [43] and in line with numerous previous investigations in the field of AAL and smart home acceptance research [26, 39], wherein data security and privacy mostly present perceived barriers and thus, acceptance-relevant criteria.

### 5.4 Limitations and Future Research

Although the presented two-step empirical study revealed insights into the acceptance of smart home and AAL systems considering users with different experiences concerning disabilities, some limitations concerning methodological approach and sample should be considered for future research in this field.

Initially, the study was a first approach comparing users with different experiences in the context of care and disabilities; therefore, we concentrated on the evaluation of crucial benefits and barriers as well as on the acceptance of our described system in general enabling smart home (e.g., heating, lighting) as well Ambient Assisted Living functionalities (e.g., remembering, monitoring). In future studies, we will be able to integrate more detailed aspects, e.g., relationship between privacy and safety, detailed data security evaluation (period and kind of data storage, data access), that have not been considered so far. Second, the study focused on a holistic multi-functional and its evaluation and not on an evaluation of single technologies and functions as they have already been largely researched. It would be very interesting to analyze if scenarios with slightly divergent descriptions (e.g., adding or changing functions) of a holistic AAL system will be evaluated differently. Of course, the scenario-based approach of our study must be noticed: the evaluation based on a fictional and not on a real AAL system and therefore, we will conduct an evaluation of the real system and will compare the scenario-based and real evaluations as soon as the system is ready to be integrated in care institutions as well as private home environments.

Further, there are also some aspects concerning the sample which should be considered for future studies. The study's sample size was adequate, but the study should be replicated in even larger and especially more representative samples: this was especially true for gender because the sample contained a higher number of women than men. In our sample, age was not related to disabilities or current care needs and therefore our study reached younger as well as older people with disabilities. Nevertheless, it is desirable to try to reach a higher proportion of "old and disabled" people in order to be able to focus on the new phenomenon of "old" disabled people [8] and on the requirements and wishes of these people. A last cultural aspect refers to the fact that the present study addressed German participants and represents a single country perspective with a country-specific health care system. Thus, a comparison of smart home and AAL technology acceptance depending on different countries and their specific characteristics would be desirable to compare future user needs culture-specifically.

## 6 Conclusion

Addressing the increasing challenge to tackle demographic change and care of elderly and disabled persons, the development of smart home and AAL technologies is a promising approach. The acceptance of users and the broad willingness to use these technologies at home represent the critical cornerstone for a sustainable adoption of those technologies. While research increasingly provides differentiated insights into acceptance research in the context of age and generation, so far, sparse knowledge is prevailing about the acceptance of disabled persons and resulting care needs.

The current study therefore concentrated on the perspective of persons having different experiences with disabilities and care needs. A two-tier approach was pursued: First, a qualitative interview was conducted to gain insights into opinions, wishes, and needs of disabled persons. In addition to the affected persons themselves, we also included relatives of disabled persons, professional caregivers, and, as a control group, persons without experience with disabilities. Second, a questionnaire study was carried out, in which we explored perceived benefits and barriers, use conditions, and acceptance of AAL technologies.

The results showed that acceptance as well as perception of benefits and barriers regarding AAL and smart home technologies depend on user diversity and particularly usage motives and barriers are pronounced and weighted differently referring to user groups having different experiences with disabilities and care needs.

The presented study enabled an identification of user-specific benefits and barriers of smart home and AAL technologies as well as building an acceptance model containing perceived benefits, perceived barriers, their trade-offs, system acceptance and the influence of user diversity factors. Thus, the current study contributes to a deeper understanding of user-specific AAL and smart home technology acceptance focusing on disabilities and care needs. A premature and iterative integration of users with different experiences and needs in the development process of assistive technologies is not merely desirable but also necessary to increase user acceptance and adoption in the context of innovative AAL and smart home technologies.

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