Privacy, Data Security, and the Acceptance of AAL-Systems – A User-Specific Perspective

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Abstract. Rising care needs, higher proportions of older, diseased, or disabled people, and an increasing deficiency of qualified care staff due to demographic changes are major challenges in western societies. Ambient Assisted Living (AAL) technologies represent one approach to face these challenges. Besides technological developments and implementations, focusing on user acceptance (including diverse stakeholder perspectives) is important for a successful rollout. As the most previous studies focus on age-related issues, this paper emphasizes especially on people with care needs due to a disability. In particular the acceptance of an AAL system is investigated considering the trade-off between perceived benefits (e.g., increasing autonomy) and perceived barriers (e.g., invasion in privacy, to "abandon" data security). Using a quantitative online questionnaire, decisive use conditions are identified, and the trade-offs and AAL-acceptance are evaluated comparing four user groups: "healthy people" without experiences with disabilities, disabled people, family members, and professional care givers. Results indicate that experience with disabilities influence the acceptance and relevant use conditions of AAL systems as well as the trade-offs between benefits and barriers. The results demonstrate the relevance to include diverse user groups (age, diseases, disabilities) and their specific needs and wishes into the design and evaluation process of AAL technologies.

Keywords: Ambient assisted living (AAL) technologies · Technology acceptance · User diversity · Privacy & data security · Disabilities & care needs

1 Introduction

Demographic change and a resulting increasing number of older people and people in need of care represent a major challenge for today's society and poses exceptional burdens for the care sector [1, 2].

The proportion of typical age-related diseases such as diabetes, dementia, or cardiovascular diseases increases continually and plays an important role for the care sector [3–5]. However, age-independent diseases and disabilities are also of importance and should be taken into account as they also effect huge needs of care and assistance [6]. In addition, it should be noted that there is a comparably new phenomenon of an first "old" generation of disabled people: on the one hand, due to medical and technical developments (e.g., innovative therapies and medicines), on the other hand, especially in Europe - due to the specific

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historical background of euthanasia murders during National Socialism [7]. Therefore, the three factors age, diseases, and disabilities are relevant and have to be considered concerning increasing care needs and related challenges.

In recent years, numerous single-case solutions but also complete ambient assisted living systems were developed in order to provide solutions for the care sector [8]. These systems are able to monitor medical parameters, to detect falls as well as to facilitate living at home using smart home technology elements [9–11]. Current research focuses specifically on holistic AAL systems, that combine various functions, are optimally economical, retrofittable, and customizable to individual needs of diverse users. Besides technological developments, it is important to investigate to which extent such AAL systems are desired and accepted by whom and under which conditions. Especially the trade-off between perceived advantages (mostly increased safety) and perceived barriers (e.g., data security, privacy) is discussed with regard to AAL technologies and their usage. As existing studies with regard to the acceptance of AAL technologies have mainly focus on age [12, 13] or gender [14] as affecting user factors and have not considered people with diseases and disabilities so far, this paper investigates the acceptance of AAL systems with focus on disabled people and people having experiences with disabilities (family members, caregivers). The study aims for a comparison of different user perspectives on use conditions, privacy, safety, data security, and the acceptance of AAL systems.

1.1 Ambient Assisted Living (AAL) Technologies

In the last years, different types of monitoring technologies (e.g., microphones, cameras, and movement sensors) are integrated into people's living environments in order to enhance safety by detecting falls and emergencies. Within this development, the number of commercial obtainable AAL systems as well as AAL research projects increased significantly. Currently, modular and multifunctional systems are available on the market and include smart home functions (e.g., sensors for lighting or heating control or automatic opening/closing of doors and windows), fall detection, and health care applications such as a reminder for blood sugar measuring. These systems are ready to be integrated in private home environments [15, 16], in hospitals [17], or nursing homes [18]. Besides commercially available solutions, some research projects put the main stress on a development of holistic AAL systems [19, 20]. In contrast to most commercial solutions, these research projects consider future users iteratively in the development process of AAL systems [21]. The future user should generally be considered in development processes, as the user's perspective is decisive for a successful integration of technologies in their everyday life [22].

Although AAL technologies and systems have the potential to increase safety and to facilitate the everyday life of older, diseased, or disabled people, they are presently not broadly integrated into private home environments. To understand this phenomenon, we have to focus on potential users of these systems (together with their individual characteristics), their perceptions, perceived use conditions, and their willingness to accept AAL technologies.

1.2 Acceptance of AAL Technologies

So far, AAL technologies have mostly been perceived and evaluated positive acknowledging the necessity and usefulness of technical support [20, 22]. In contrast, fears, caveats, and acceptance barriers - in particular a feeling of isolation [23], feeling of surveillance, and fears of an invasion of own privacy [24] - were present if people were asked to think about an integrated AAL system in their personal home environment. To understand this obvious trade-off between the perceived barriers (in particular enhanced safety) and perceived barriers (especially doubts on preservation of privacy and data security) it is necessary to consider technology acceptance and the diversity of potential AAL users.

Traditional technology acceptance models like TAM or UTAUT are only limited suitable, as AAL systems address especially older, diseased, and frail people with individual prerequisites, desires, and fears [25]. We presume that these user factors lead to a different prioritization of most important (perceived) benefits and barriers and to a different acceptance and willingness to use an AAL system. Hence, the following section presents an overview of research results focusing on the acceptance of AAL systems and different user groups.

Older people's perceived benefits and barriers of AAL technologies have widely been investigated using different methodological approaches such as focus groups [26, 27] or interviews [28, 29]. Older participants acknowledge the advantages of the possibility to stay longer in their own home, they understand the lack of care staff, and regard AAL technologies as a chance. In contrast, the participants express concerns about a dependency on technologies, a lack of personal contact ("replacing" staff by technology) as well as concerns about data security and privacy within the mentioned qualitative but also in quantitative studies, e.g., [30]. While numerous projects with regard to AAL technologies and smart homes focus solely on the technological parameters, some recent projects, e.g., [19], integrate future users into the system's development, design, and evaluation process [31].

So far, research for AAL technologies has mainly concentrated on older people with age-related chronic or physical illnesses. As assistive technologies could also be beneficial for people with disabilities (e.g., supporting mobility and communication, enhancing autonomy) and age-related illnesses come along with disabilities more frequently [7], disabled users should also be addressed.

Some occasional studies summarized and investigated to which extent different diseases and disabilities affect the use of medical technologies, e.g., [32, 33], and focus especially on the explanation why numerous existing technologies were not used or rejected. Existing research on disabled or diseased people's AAL acceptance are all on a comparatively unspecific, superficial, and on a theoretical level mostly not integrating or asking disabled people directly for their opinions, whishes, and needs. Hence, this is precisely where research is wanted: in particular disabled people have to be integrated in the development and design of AAL technologies and systems.

To do especially justice to people in needs of care, it is important to consider also the perspectives of professional care givers or family members in order to receive a preferably full picture about difficulties in the everyday live, desires, and ideas. Within AAL acceptance research, requirements as well as professional and family caregivers'

perspectives on AAL systems have been considered separately and deliver first insights into different perspectives on the acceptance of AAL technologies [e.g., 34, 35]. However, they do not allow to directly compare the perspectives of different user groups (older people, diseased or disabled people, family members, professional care givers), as they each mainly focus on a specific user group and use no equivalent or comparable methodological approaches for different user groups.

The acceptance of AAL technologies has hardly been investigated with regard to disabled people and people with special care needs so far. As there is only sparse knowledge about the interaction of the described challenging factors (age, diseases, disabilities and resulting needs in assistance and care), these factors were addressed in the present study focusing on the perspectives of different user groups (disabled people, family members, professional caregivers).

2 Methodology

In this section, the applied research design is presented. First, the research approach with a preceding qualitative interview study is shortly introduced, which was taken as a basis for the subsequent quantitative study. Further, the quantitative study's empirical design and the sample are described. Our study addresses the following essential research questions:

1. How do participants evaluate the described AAL system and which use conditions are important?
2. Are perceived benefits (e.g., autonomy, independency) or barriers (especially privacy and data security) more important for its acceptance?
3. To which extent do age, experiences with disabilities, and current care needs influence the AAL system's evaluation and especially the trade-off between perceived benefits and barriers?

2.1 Research Design and Qualitative Pre-study

Previous studies on the acceptance of AAL technologies have mostly considered age as influencing user factor so far. Instead, developing AAL technologies especially for people with disabilities and investigating the acceptance of AAL technologies focusing on disabled users have prevalently not been considered. In addition, the inclusion of other perspectives (e.g., professional caregivers, relatives, and family members of disabled people) is also immensely important as they can support and complete the understanding of disabled and care-dependent user's wishes and requirements.

Within a qualitative interview study (with disabled people, caregivers, and family members of disabled people, n = 9, age 26–62, M = 36 years), perceived motives and perceived barriers of using an AAL system were initially identified. Further, use conditions were determined dependent on the different participant's perspectives and especially the trade-offs between perceived benefits (e.g., increased safety, relief) and perceived barriers (i.e. in particular privacy and data security) were intensely discussed. One major condition nearly all interview participants mentioned was the *customization*

of the used technologies. Technical solutions should fit to individual and personal needs of users – which is not specific for disabled persons - but as all people are different, the wishes and grades for customization become even more essential for user acceptance. Therefore, also *user-centered design* within the development process is mentioned as a key condition. *Reliability* and *usability* are important factors for technology acceptance mentioned by most of the participants as well. Another condition for one interview partner was the *unobtrusiveness* of assistive devices, whereas it was mentioned that people (disabled by birth) have learned to deal with the fact the surrounding directly realizes their handicap. Therefore, this condition could have a diverse impact on acceptance. *Control* was also addressed by several participants and a simple on-off-switch for the whole AAL-technology was suggested as key condition to gain intimacy. Some interview partners not only mentioned user oriented individualization but also the *situational and smart technology adaption* – the AAL technology should realize "when to switch on lights" or "help getting up from the sofa". Besides these technical challenges, all participants mentioned the *funding by health insurance companies* as a major condition to actually use AAL-technologies and last but not least, the usage of these technologies should also be *fun*.

2.2 Questionnaire Design

The questionnaire consisted of several parts and its items were developed based on the findings of the preceding interview study. The first part addressed demographic aspects, such as age, gender, educational level, and income.

Following this, the participants were asked to indicate their attitudes towards technology using four items ($\alpha = .802$) [36], towards technological innovations ($\alpha = .808$) also using four items, towards privacy using 8 items ($\alpha = .718$; based on [37] and expanded by aspects from the interviews), and towards data security (using 14 items, $\alpha = .874$; also based on [37] and expanded by aspects from the interviews) including four different dimensions: general attitude towards data security, personal data usage, effects of data usage, and general handling of data. All items concerning data security and privacy are presented in Fig. 1 in Sect. 3.1.

The next part addressed experiences with disabilities: the participants were asked to indicate if themselves have a disability (a), if they are a family member of a disabled person (b), if they are a caregiver of a disabled person (c), or if they have no experiences with disabilities (d).

A scenario was designed in order to guarantee that all participants refer to the same basis according to the evaluation of an AAL technology. Depending on their expertise (need of care, experience with disabilities), the participants were introduced to the scenario specifically. For cases b, c, and d, the participants were asked to put themselves in a disabled person's position (respectively the person they are related with or they care (b,c)) while evaluating the AAL scenario. Participants without experiences with disabilities and need of care were asked to imagine that they would be in need of care. Within the scenario, the participants should imagine that an specific invisible AAL system was integrated in their personal home environment and included diverse functions: automatic opening and closing of doors and windows (by sensors), hands-free kit for phoning (by

integrated microphones), monitoring of front door area (by cameras), fall detection (by sensors in floor and bed), automatic lighting control (by light sensors and position detection) and configuration of home temperature (by smartphone).

Subsequent to the scenario, the participants were asked to assess different use conditions (11 items, $\alpha = .808$; based on the qualitative interview study's findings, see 2.1), the trade-off between perceived benefits (e.g., to increase autonomy) and perceived barriers (e.g., feeling of surveillance, privacy, data security) (using 4 items; $\alpha = .866$), and the acceptance of as well as intention to use the described AAL system (using 8 items; $\alpha = .899$). All items are presented within the figures in Sect. 3.

Finally, the participants should evaluate eight different statements concerning the acceptance or rejection as well as the behavioral intention to use the described AAL system. Completing the questionnaire took on average 15 min and data was collected in an online survey in summer 2016 in Germany.

2.3 Sample

Overall, 279 participants volunteered to participate in our online questionnaire study. As we only used complete data sets for further statistical analyses, a sample of $n = 182$ data sets remained. 62.1% of the participants were female, 36.3% male (1.6% did not want to indicate their gender). The participants were on average 38.7 years old ($SD = 13.95$; $min = 20$; $max = 81$) and the educational level was high with 46.7% holding a university degree and 14.8% a university entrance diploma. In accordance with experience with disabilities, 51 participants indicated to be disabled (28.0%), 12.1% ($n = 22$) were professional caregivers, 35 participants were relatives of a disabled person (19.2%), and 40.7% ($n = 74$) had no experience with disabilities.

In addition, the self-reported technical self-efficacy was on average positive ($M = 4.5$; $SD = 1.0$; $min = 1$; $max = 6$) and the attitude towards technology innovations was slightly positive ($M = 3.9$; $SD = 1.0$; $min = 1$; $max = 6$).

Further, 79 (43.4%) participants indicated to need care or that the person they care or they are related with needed care (56.6% indicated to be not in need of care). These factors are related only in parts: age is not linked with experience with disabilities ($r = -.13$; $p = .08 > .05$) nor with current care needs ($r = -.10$; $p = .20 > .05$). In contrast, age is related with gender ($r = .20$; $p < .05$; 1 = female; 2 = male). As expected, experience with disabilities correlates with current care needs ($r = .61$; $p < .01$).

2.4 Data Analysis

Item analyses were calculated to ensure measurement quality before descriptive and inference analyses were carried out. Cronbach's alpha > 0.7 indicated a satisfying internal consistency of the scales. Data was analysed descriptively and with respect to the effects of user diversity, by (M)ANOVA procedures (level of significance was set at 5%). To analyze the impacts of experiences with disabilities and care needs on AAL acceptance and the evaluation of privacy and data security, we choose the factors age, experience with disabilities, and acute care needs for further analysis.

3 Results

Within this section, the study's results are presented and structured as follows: first, an overview of the evaluation of attitudes towards data security and privacy is presented. In a second step, the results concerning the acceptance of the described AAL system is detailed, followed by the results of acceptance-relevant use conditions. Finally, the evaluated trade-offs between data security, privacy, and the perceived benefits of an AAL system are described. In each case, the results are presented first for all participants and then potential influences of user factors (age, disabilities, care needs) are considered.

3.1 Attitudes Towards Privacy and Data Security

As it was shortly mentioned in the methodology section, the attitudes towards data security (Fig. 1) and privacy (Fig. 2) were assessed by using 14 or rather 8 items.

Fig. 1. Evaluation of data security items (all participants).

Data Security: The average needs for data security were on a moderate level with regard to all participants (M = 4.1; SD = 0.8; min = 1; max = 6). Zooming in the attitude items, *"…control who has access to data"* (M = 5.3; SD = 0.9) was the most important aspect, followed by *"…society should deal more cautiously…"* (M = 5.0; SD = 1.1) and *"data security is important for me"* (M = 4.9; SD = 1.0). In contrast, *"… does not matter to me because I have nothing to hide"* (M = 2.0; SD = 1.2) was the most rejected aspect, while four other items, e.g., *"I do not know who may be interested in my data"* (M = 3.0; SD = 1.5) and *"by uploading data I can live more independently"* (M = 3.3; SD = 1.4) were slightly rejected. The remaining items were evaluated rather positive, e.g., *"uploading*

data makes me vulnerable" (M = 4.1; SD = 1.3) or *"I am afraid that my data will be attacked and abused"* (M = 3.9; SD = 1.4).

Interestingly, MANOVA analyses revealed that the attitude towards data security differed not with regard to age ($F(28, 300) = .761$; $p = .805 > .05$; n.s.), experiences with disabilities ($F(42,453) = .933$; $p = .594 > .05$; n.s.), nor with care needs ($F(14,149) = .933$; $p = .642 > .05$; n.s.).

Privacy: The average needs for privacy were also on a moderate level with regard to all participants (M = 4.4; SD = 0.7; min = 1; max = 6). The participants indicated that *"privacy is very important"* (M = 5.1; SD = 1.0), they want to *"be able to control own privacy…"* (M = 5.1; SD = 1.0), and they *"…respect the privacy of others"* (M = 5.1; SD = 0.9). The participants also agreed with the statements *"… should be handled more carefully"* (M = 4.7; SD = 1.1) and *"… I have enough privacy"* (M = 4.4; SD = 1.1). In contrast, the more concrete fear that *"private conservations and intimate details will be whispered"* (M = 3.6; SD = 1.4) was rated rather neutral, while the statements *"… no sense to worry about privacy as you can not protect it anyway"* (M = 2.4; SD = 1.2) and "*I wonder why such a hype is made about privacy*" (M = 2.3; SD = 1.3) were rejected.

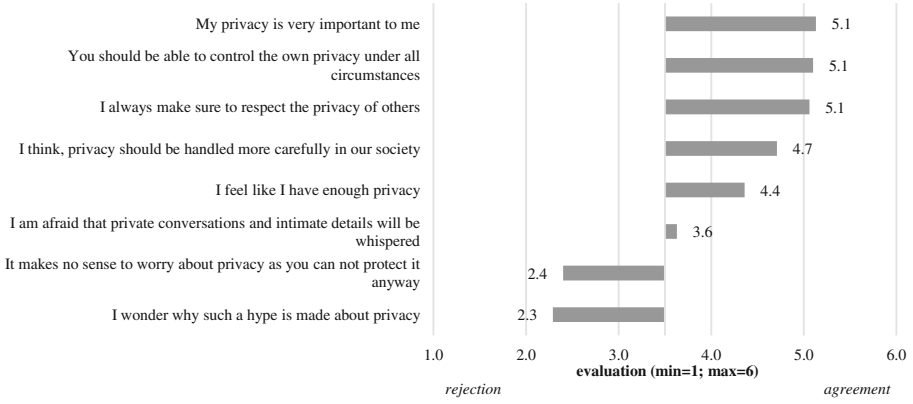

Fig. 2. Evaluation of privacy items (all participants).

Concerning the attitude towards privacy, MANOVA analyses also revealed that the attitude towards privacy differed not with regard to age ($F(16, 308) = .636$; $p = .854 > .05$; n.s.), experiences with disability groups ($F(4,465) = .989$; $p = .479 > .05$; n.s.), nor care needs ($F(8,153) = .496$; $p = .858 > .05$; n.s.). Instead, the combination of all three user factors ($F(24,465) = 1.544$; $p < .05$) and the combination of care needs and experience with disabilities ($F(16,308) = 1.786$; $p < .05$) influenced the attitude towards privacy significantly.

3.2 Acceptance of an AAL System

The attitude towards AAL technologies was on average positive (M = 4.6; SD = 1.0) and showed that the described AAL system was accepted by the participants. In detail (see Fig. 3), the items with regard to an intention to use the AAL system and care needs *("…due to care needs"* (M = 4.7; SD = 1.1); "*… reduce my care needs"* (M = 4.5; SD = 1.3)*)* were evaluated highest. The participants rated the three statements concerning a concrete intention to use the AAL system rather positive, while the item *"I would install…"* (M = 4.3; SD = 1.4) was assessed higher than the aspects *"I like to use these AAL technologies"* (M = 4.0; SD = 1.4) and *"I can imagine to use this AAL system now"* (M = 3.8; SD = 1.6). The three negative acceptance statements were all rejected (e.g., *"I think such AAL systems are superfluous"* (M = 1.9; SD = 1.1).

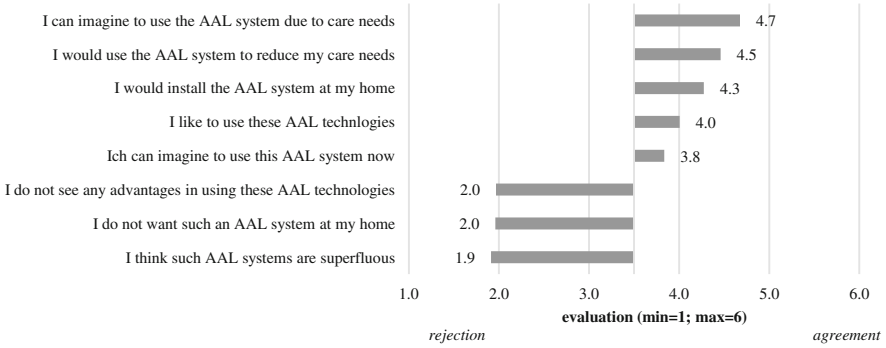

Fig. 3. Evaluation of AAL acceptance items (all participants).

Considering different user factors, MANOVA analyses revealed significant differences with regard to age ($F(16,308) = 2.104$; $p < .01$), experiences with disabilities ($F(24,465) = 2.060$; $p < .01$), and care needs ($F(8,153) = 3.779$; $p < .01$).

With regard to experiences with disabilities, the negative statements were rejected lowest by the professional caregivers (e.g., *"I do not want such an AAL system at my home"* ($F(3,162) = 4.907$; $p < .01$), which therefore seemed to have a higher negative attitude towards AAL systems than the other groups. This was also true for the intention to use an AAL system, to which statements all user groups agreed, while the professional caregivers showed the lowest agreement. The group of "not experienced" participants showed highest agreements concerning the *"in case of care needs"* items. This evaluation changed with regard to the statement *"I can imagine to use this AAL system now"*, which was evaluated clearly higher by the group of disabled people (M = 4.3; SD = 1.3) compared to the not-experienced participants (M = 3.5; SD = 1.7; post-hoc-tests: Tukey's HSD).

Concerning care needs, nearly all items with regard to the AAL system's acceptance differed significantly. The overall acceptance was a little higher for people with care needs (M = 4.7; SD = 1.0) than for people without care needs (M = 4.5; SD = 1.0; $F(1,162) = 7.309$, $p < .01$). The negative statements were significantly more rejected by

people in need of care compared to people without care needs, e.g., "*I do not want such an AAL system at my home*" ($F(1,162) = 10.187$; $p < .01$). While the intention to use items with regard to care needs (e.g., *"…due to care needs"* ($F(1,162) = 4.441$; $p < .05$)) were only slightly more accepted by people with care needs than by people without care needs, the differences were more obvious considering the concrete intention to use items: participants in need of care showed clearly higher agreements for all items (e.g., *"I would install the AAL system at my home"* ($M = 4.5$; $SD = 1.3$; $F(1,162) = 7.107$; $p < .01$) than the participants without care needs ($M = 4.1$; $SD = 1.5$).

3.3 Conditions for Using an AAL System

As introduced before, the participants evaluated different conditions for using an AAL system at their own home. Figure 4 shows the descriptive results of all evaluated use conditions for all participants.

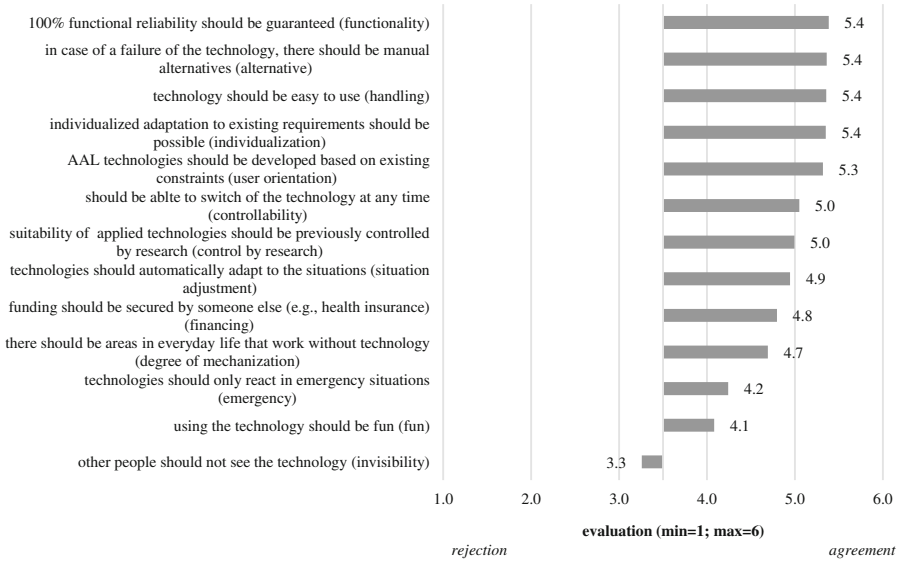

Fig. 4. Evaluation of use condition items (all participants).

"*100% functionality*" ($M = 5.4$; $SD = 0.9$), "*manual alternatives in case of failure of the technology*" ($M = 5.4$; $SD = 1.0$), an "*easy handling*" ($M = 5.4$; $SD = 0.9$), "*individualized adaption*" ($M = 5.4$; $SD = 0.9$), and "*user-oriented development based on existing constraints*" ($M = 5.3$; $SD = 0.8$) were rated highest and represented the most important use conditions. "*Controllability*" ($M = 5.0$; $SD = 1.2$), "*control by research*" ($M = 5.0$; $SD = 1.1$), "*situation adjustment*" ($M = 4.9$; $SD = 1.0$), "*financing*" ($M = 4.8$; $SD = 1.1$), and "*degree of mechanization*" ($M = 4.7$; $SD = 1.4$) received also agreement and are of importance for AAL system usage.

In contrast, the statements *"technologies should only react in emergency situations"* (M = 4.2; SD = 1.4) and *"using the technology should be fun"* (M = 4.1; SD = 1.3) were rather agreed and thus, they did not represent important use conditions. The fact that *"other people should not be able to see the technology"* (M = 3.3; SD = 1.4) was slightly rejected by the participants and thus, it constituted no relevant use condition.

MANOVA analyses revealed significant overall effects concerning the evaluation of use conditions for experience with disabilities ($F(39,456) = 1.444$; $p < .05$), but not for age ($F(26,302) = .905$; $p = .602 > .05$; n.s.) or care needs ($F(13,150) = .963$; $p = .490 > .05$; n.s.). Significant differences were found in particular with regard to the items "*control by research*" ($F(3,181) = 2.576$; $p < .05$), "*financing*" ($F(3,181) = 2.863$; $p < .05$), and "*degree of mechanization*" ($F(3,181) = 4.288$; $p < .01$). As it is shown in Fig. 5, "*control by research*" was most important for not-experienced persons (M = 5.2; SD = 0.9) and the group of professional caregivers (M = 5.2; SD = 1.0), while it was minor important for family members (M = 4.9; SD = 1.2) and especially disabled persons (M = 4.7; SD = 1.3). "*Financing*" (e.g., by health insurance) was comparatively most important for the group of disabled participants (M = 5.2; SD = 1.1) and professional caregivers (M = 5.1; SD = 1.0), followed by family members (M = 4.7; SD = 1.2), and least important for the group of not-experienced participants (M = 4.5; SD = 1.1). The "*degree of mechanization*" was clearly the most important use condition for the group of professional caregivers (M = 5.5; SD = 0.7), while it was minor important for not-experienced (M = 4.7; SD = 1.4) and disabled participants (M = 4.6; SD = 1.4), and least important for the group of family members (M = 4.3; SD = 1.5).

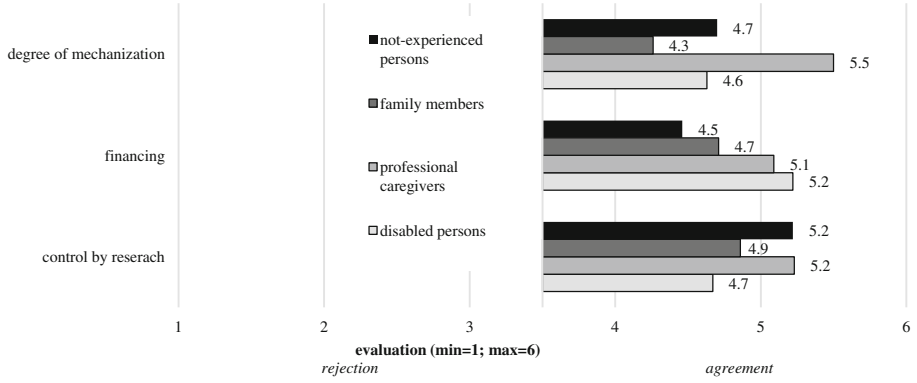

Fig. 5. Significant differences in the evaluation of use conditions (experience with disabilities groups).

3.4 Trade-Offs Between Benefits and Barriers

Figure 6 presents the results of a trade-off between different benefits (independency, autonomy, time savings) and barriers (data security, privacy) of AAL system usage. Overall, the participants rather agreed that it is fine to abandon a piece of privacy in favor for a "*more independent life*" (M = 4.1; SD = 1.2). Similarly, they showed also

agreement concerning the statement that *"…autonomy will be more important than data security*" (M = 4.1; SD = 1.3). Likewise, the statement "*if AAL technologies need personal data for their automatic improvement, it will be okay to upload them*" (M = 3.9; SD = 1.3) was on average slightly endorsed by the participants. In contrast, "*time savings*" (M = 3.2; SD = 1.4) were slightly rejected and were not seen as a relevant benefit, for which the upload of sensitive data would be justified.

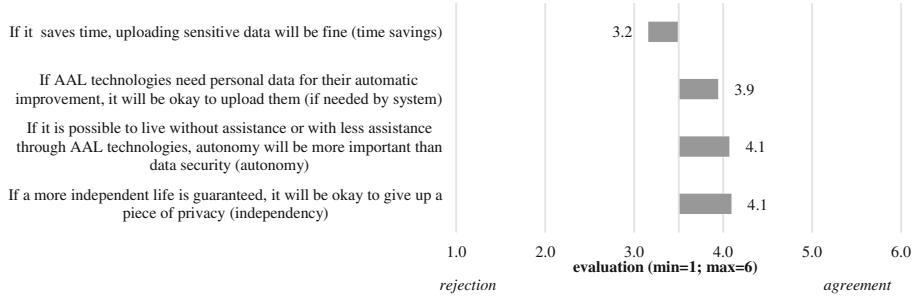

Fig. 6. Evaluation of items with regard to a trade-off between perceived benefits and data security as well as privacy (all participants).

MANOVA analyses revealed that this trade-off was affected by the user factor experience with disabilities but not by care needs ($F(4,159) = 2.156$; $p = .076 > .05$; n.s.) and age ($F(8,320) = 1.631$; $p = .115 > .05$; n.s.). In detail, "*independency*" ($F(3,181) = 3.610$; $p < .05$) and "*autonomy*" ($F(3,181) = 5.019$; $p < .01$) were evaluated clearly different by the four experience with disabilities groups (see Fig. 7):

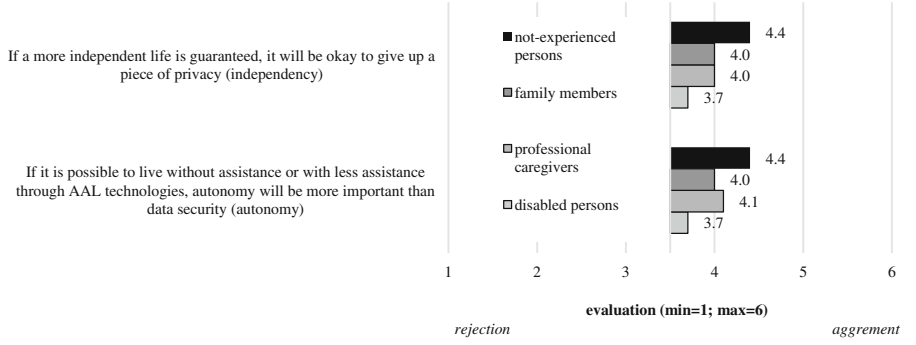

Fig. 7. Significant differences in the evaluation of the trade-off between benefits and barriers (experience with disabilities groups).

As it is shown in Fig. 7, in particular the not-experienced group and the disabled participants' group differed significantly in their evaluation (post-hoc-tests: Tukey's HSD): the not-experienced group agreed more clearly that *"independency"* (M = 4.4; SD = 0.9) and *"autonomy"* (M = 4.4; SD = 1.1) were more important than privacy and

data security, while the disabled group evaluated both statements rather neutral (*"independency":* M = 3.7; SD = 1.4; *"autonomy"* M = 3.7; SD = 1.5).

Figure 8 presents the evaluation of three final statements concerning AAL usage, privacy, and data security for all participants. The statement *"since there is no unassailable network, you should avoid AAL technologies"* was rejected by the participants (M = 2.4; SD = 1.1) and hence, data security was no reason to avoid AAL technologies in general. Further, the participants rated the item *"the restriction of privacy by AAL technologies is wrong"* (M = 3.5; SD = 1.4) completely neutral. Finally, the participants endorsed that "*the use of AAL technologies requires 100% data security"* (M = 4.9; SD = 1.3).

Fig. 8. Evaluation of items with regard to a AAL systems and their influence on data security and privacy (all participants).

MANOVA analyses revealed that the final evaluation of statements with regard to AAL usage, privacy, and data security was influenced by the user factor experience with disabilities ($F(9,486) = 2.474$; $p < .01$) as well. However, it was not affected by age ($F(6,322) = .715$; $p = .638 > .05$; n.s.) or care needs ($F(3,160) = 2.061$; $p = .108 > .05$; n.s.).

As it is shown in Fig. 9, the evaluation of the three respective items differed clearly referring to the experience with disabilities groups. The item "*…you should avoid AAL technologies*" ($F(3,181) = 2.972$; $p < .05$) was most rejected by the group of family members (M = 2.1; SD = 1.1), while the professional caregivers showed the lowest rejection (M = 2.7; SD = 1.2). The statement "*the restriction of privacy by AAL technologies is wrong*" ($F(3,181) = 3.693$; $p < .05$) was rejected by the not-experienced (M = 3.2; SD = 1.2) and the group of family members (M = 3.3; SD = 1.4), while the professional caregivers (M = 3.7; SD = 1.2) and the disabled persons slightly agreed (M = 3.9; SD = 1.6). Finally, the item "*the use of AAL technologies requires 100% data security*" ($F(3,181) = 2.972$; $p < .05$) was most endorsed by disabled persons (M = 5.2; SD = 1.1), professional caregivers (M = 5.1; SD = 0.9), and the not-experienced persons (M = 4.9; SD = 1.2), while the group of family members showed a comparatively lower agreement (M = 4.5; SD = 1.6).

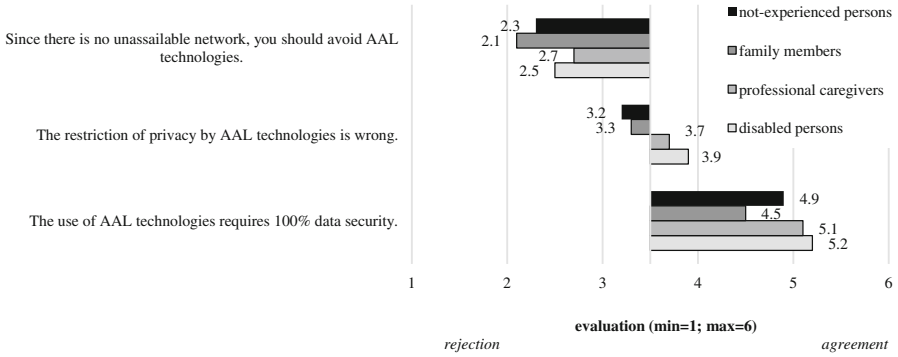

Fig. 9. Final evaluation of statements with regard to AAL usage, privacy, and data security (experience with disabilities groups).

4 Discussion

The present study revealed insights into acceptance patterns, relevant use conditions, and trade-offs with regard to AAL systems in home environments. We considered and compared different user perspectives (e.g., age, disabilities, and care needs) in order to understand specific needs of diverse potential users. The results provide valuable insights into user-specific as well as acceptance-relevant criteria in the context of AAL systems and should be taken into account for the development and design of AAL technologies.

4.1 User-Specific Acceptance of AAL Systems

First, it has to be mentioned that user diversity did not have a significant impact on the attitudes towards privacy and data security and thus, these factors are generic key conditions for AAL acceptance within all participants. However, user diversity had a significant influence on acceptance and on the direct trade-offs between perceived benefits and barriers (see Sect. 3.4), which is subsequently discussed for distinct results of selected user groups.

In line with previous research results, e.g., [20], our results demonstrate that a holistic AAL system with various functions is generally accepted and rated positive by all respondents. In particular, the intention to use the system is universally present (if care needs are mentioned within the items (see Sect. 3.2)) and differs only slightly with regard to the different user perspectives. In contrast, significant differences between the user perspectives are present, if a concrete intention to use was mentioned without the context of care needs: generally speaking, older people, disabled people, and people in need of care showed a clearly higher intention to use and acceptance of an AAL system than presumably healthy "not-experienced" people. Thus, the intention to use an AAL system is influenced by the user factors experience with disabilities and care needs.

Considering the different user perspectives, the *group of professional care givers* is striking with respect to their evaluations: in comparison with all other groups, they have a more negative attitude towards the described AAL system. Especially in contrast to users in need of care - who might be depending on assistive technologies and might have already experienced an intrusion of intimacy - the professional caregivers have a significantly more declining position towards AAL technologies. Although they might gain support in their everyday stressful job, the caregivers show least acceptance for technical solutions. This could be explained by diverse theories: on the one hand, the increasing use of technologies can come along with the fear of job loss due to a new technology or to be "replaced" by technology [e.g., 38]. Additionally, the use of technologies in the care sector raise ethical issues [39], for instance, to what extent is it acceptable that technological devices might replace time and everyday tasks usually caregivers would spent with residents? In the context of social jobs and working environments, individual influences of people and their perceptions are of major importance. Hence, much more research is necessary that not only focuses on scenario-based evaluations but moreover on real life scenarios, real working surroundings, and considers different stakeholder's perspectives.

This study's *disabled participants and participants with current care needs* perceived the in the scenario introduced AAL system as useful, helpful, comfortable, and future-orientated. However, these people in need for assistance have the most sensitive attitude towards privacy and data security concerns (similar to previous research results [40]). This group's results showed that the direct trade-off between perceived benefits (especially increased autonomy and safety) and perceived barriers (in particular data and privacy concerns) of ambient assisted living technologies are balanced and thus, both aspects influence the acceptance with a somehow similar weighting. To meet the individual requirements for privacy and data security, it is important to consider wishes and ideas, e.g., this study's participants suggested a selective on-off-switch of video monitoring functions (in line with previous studies [28]). Therefore, the early integration of people in need of care into the development process of AAL technologies is crucial for the acceptance and to reduce perceived barriers. The overall impression of this study was that the participating disabled people showed a high willingness to be part in the development and evaluation process and desired to be asked and involved more frequently.

4.2 Limitations and Further Research

The empirical approach of this study revealed valuable insights into the acceptance of AAL technologies, relevant use conditions, and trade-offs between perceived benefits and barriers focusing on different groups of future users. However, there are some limitations concerning the applied method and sample that should be taken into account for future research.

First of all, this study's evaluation based on a scenario and hence, a fictional system and not a real system was assessed. At a later stage, it will be possible to evaluate real systems within research projects. Then, it will be possible to compare the scenario and the real system evaluations. This way, it is enabled to investigate if the evaluations on

a hypothetical level are comparable to the agreement or rejection of the real system [41]. Likewise, it will be very interesting to analyze whether the system really is efficient and beneficial for different user groups (e.g., relief in everyday life, increased autonomy).

Further, an entire AAL system with different functions and technologies was evaluated. In future studies it could be interesting to investigate if slightly different systems (e.g., adding or changing functions) will be assessed similarly.

In addition, a more detailed investigation of trade-offs (e.g., safety vs. privacy, increased independency/autonomy vs. invasion of privacy and data security) using other methodological approaches (e.g., conjoint analyses) would provide more information about concrete decisions between different motives that are relevant for AAL acceptance.

Also some aspects concerning the sample could be improved and continued in future research: first, this study's sample size was adequate, but the study should be replicated in even larger and especially more balanced samples. As this study contained a higher proportion of women than men, future studies should focus on a more gender-balanced sample. Further, age was not related to disabilities or current care needs within our study and thud, we reached similarly younger as well as older people with disabilities. To be able to focus also adequately on older disabled people [7], future studies should try to reach higher proportions of older and disabled people. Another important aspect is that our study focused on physically incapacitated people. However, the care needs of mentally disabled people pose a major challenge for the care sector and especially the care staff as well. Hence, it is very important to develop ideas and strategies how mentally disabled people could be integrated into future technology acceptance research.

A final remark refers to the fact that the present study focused on German participants and hence, it represented a perspective of a single country with a specific health care system. It would be very interesting to conduct this study in other countries in order to compare AAL acceptance as well as (disabled) users wishes, needs, and requirements depending on different cultures, countries, and backgrounds.

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