# Caregivers’ Perspectives on Ambient Assisted Living Technologies in Professional Care Contexts

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Keywords: Ambient Assisted Living Technologies, Technology Acceptance, Professional Caregivers, Data Gathering and Storage, User Diversity.

Abstract: An increasing proportion of older people in need of care presents one of the major challenges within demographic change. The development of Ambient Assisted Living (AAL) technologies is one option to face the challenges of rising care needs. Beyond technical and economic aspects, the acceptance of diverse stakeholders plays a major role for a successful implementation and rollout of those technologies. In particular, it is questionable whether and to which extent the use of assisting technologies is accepted in professional care contexts, in particular with respect to gathering and storage of data. Thus, the current study aimed for an investigation of professional caregivers’ perspectives on the acceptance of AAL technologies in professional care contexts. In a scenario-based online questionnaire, n = 287 professional caregivers evaluated perceived benefits, barriers, and acceptance of AAL technologies. Also, they indicated which data can be gathered and which specific technologies should be used to gather data. Further, data access and data storage were also under study. The results showed a reserved and critical attitude of professional caregivers towards using AAL technologies in their everyday working life and allow to analyze trade-offs between permitted gathered data and specific requested technologies in depth.

## 1 INTRODUCTION

Demographic change entails the development of more and more older people and people in need of care representing enormous challenges for today’s society and especially high burdens for the care sector (Pickard, 2015; Walker & Maltby, 2012; Bloom & Canning, 2004). In particular, geriatric and nursing care institutions suffer badly from a lack of specialists in combination with higher proportions of old and diseased people who have to be cared (Siewert et al., 2010; Shaw et al., 2010; Wild et al., 2004; Roger et al., 2011). At the same time, there is a first generation of “old disabled” people due to medical and technical developments in healthcare and otherwise also due to the specific historical background of euthanasia offenses (in particular in Europe), in which disabled people were systematically deported or even murdered (Poore, 2007). Thus, similar to the challenges for geriatric and nursing care, the sector of care and support of disabled people is also confronted with higher proportions of people in need of care and a simultaneous lack of care staff (WHO, 2012).

Summarizing, all these care areas face essentially the same challenges and questions arise how those challenges can be addressed. Technical innovations and ideas are increasingly developed in order to relieve care staff, to enable a longer opportunity to stay at home for older people, or to enhance safety in emergencies. Among those technical innovations and ideas, technical single-case solutions as well as more complex ambient assisted living systems (AAL) (Memon et al., 2014; Frank & Labonnote, 2015) exist that detect falls and emergencies, monitor vital parameters, or enable living longer at home using smart home technology elements (Cheng et al., 2013; Baig & Gholamhosseini, 2013; Kleinberger et al., 2007; Rashidi & Mihailidis, 2013).

Besides technical functionality and possibilities, current research reveals that those systems are rarely used in real life and especially in professional environments (Wichert et al., 2012). The users’ acceptance is decisive for a sustainable implementation and usage of innovative technologies and systems. Hence, diverse stakeholders of AAL technologies should be addressed and their perceptions, opinions, and ideas should be investigated. Previous



Heek, J., Ziefle, M. and Himmel, S.
Caregivers’ Perspectives on Ambient Assisted Living Technologies in Professional Care Contexts.
In *Proceedings of the 4th International Conference on Information and Communication Technologies for Ageing Well and e-Health (ICT4AWE 2018)*, pages 37-48
ISBN: 978-989-758-299-8

studies indicate differences in AAL acceptance between disabled people or people in need of care and the perspective of professional caregivers. Additionally, the caregivers' acceptance of assistive technologies is a prerequisite for a successful implementation of AAL technologies in professional care contexts. Therefore, the current study especially focuses on professional caregivers' perspectives on specific AAL technologies, on gathering of data, data access, storage duration as well as perceived benefits and barriers. Based on this investigation, it is possible to integrate the caregivers' professional perspective into the design of AAL technologies. This way, specific technologies can be adapted to the needs and wishes of professional caregivers and the usage of AAL technologies in professional care contexts could potentially be increased.

# 2 ACCEPTANCE OF AAL TECHNOLOGIES IN CARE

This section presents the theoretical background of the current study starting with a short overview of current AAL technologies and systems. Afterwards, prestigious and well-known acceptance models as well as results previous acceptance studies in the context of AAL technologies for usage in professional care contexts are introduced.

## 2.1 Ambient Assisted Living

The term Ambient Assisted Living (AAL) summarizes assisting technologies or systems that contribute to maintenance of autonomy in everyday life and are especially applied in care for prevention and rehabilitation (Kleinberger et al., 2007; Georgieff, 2008). Those technologies cover a broad range of applications reaching from monitoring and detection to reminders and smart home functionalities. Here, a short overview of prototypical examples is given.

In the context of (outdoor) tracking and detection of positions, Radio Frequency Identification (RFID) tags are frequently used (Dohr et al., 2010). Further, different types of monitoring are made possible by integrating common Information and Communication Technologies (ICT) (e.g., microphones, movement sensors, or (infra-red) cameras) into people's living environments. In particular, it is aimed for enhancing safety by detection falls and emergencies in private home environments (Stone & Skubic, 2015) as well as in professional care contexts, e.g., hospitals or care institutions (Ni et al., 2012). Besides those safety-relevant functions, other types of AAL technologies aim for facilitating everyday life by using automated technologies, e.g. memory aids or home automation (Costa et al., 2009; Hristova et al., 2008). Further, also supporting communication with families, friends, and caregivers by integrating ICT in home environments is an aim of AAL (Kleinberger et al., 2007). A further area of AAL technologies are wearable technologies (e.g., emergency arm strap) worn on the body or integrated in clothes that are able to communicate with intelligent AAL systems or smart home environments (Patel et al., 2012; Memon et al., 2014). Although numerous systems and technologies are available on the market (e.g., Essence, 2017; Tunstall, 2017) or focused in current research projects (e.g., Gövercin et al., 2016), resounding success of those systems has not occurred so far, as they are only rarely used in real life (Wichert et al., 2012) and especially in professional care contexts (Isern et al., 2010).

On this basis, the question arises for what reasons those existing, assisting, and facilitating technologies are not widely used in professional healthcare contexts although they have the potential to facilitate the professional everyday life? Future users' acceptance as well as their perception of usage benefits and especially barriers are decisive for a successful integration of AAL systems in everyday life. To understand the barriers of AAL usage in professional contexts, we therefore focused on professional caregivers as potential users of these systems, their perceptions, ideas, wishes, and willingness to adopt home-integrated ICT in this study.

## 2.2 User-specific Acceptance of AAL

Previous research results revealed that AAL technologies were mostly evaluated positively and the necessity and usefulness of technical support were acknowledged by diverse groups of potential users (van Heek et al., 2017; Himmel & Ziefle, 2016; Beringer et al., 2011; Gövercin et al., 2016). Enabling an independent and more autonomous life as well as a longer staying at the own home for older, diseased and/or disabled people are strong drivers to use AAL technologies. In contrast, feelings of isolation (e.g., van Heek et al., 2017a; Sun et al., 2010), feelings of surveillance, and invasion of privacy (e.g., Wilkowska & Ziefle, 2012; Wilkowska et al., 2015; van Heek et al., 2017b) represent the most frequently mentioned barriers if people were asked to think about an integration of AAL technologies in their living environment. In more detail, numerous focus group (e.g., Demiris et al., 2004; Ziefle et al.,

2011) and interview studies (e.g., Beringer et al., 2011) with people aged above 60 were conducted in order to examine the elderly's perceptions of AAL technologies: Similar to the mentioned general positive perception, the older participants acknowledged the benefits of staying at home longer, understood the problematic lack of care staff as well as the chances and potential of AAL technologies. On the other side, they expressed fears concerning a dependency on technologies they are not able to control, a lack of personal contact referring to the concern that care staff will might be substituted by technologies, and privacy concerns. These mostly qualitative gained results have been confirmed by numerous quantitative surveys over the last years (e.g., Himmel & Ziefle, 2016).

The perspectives of professional care givers on integrating AAL technologies in professional care contexts have rarely been considered in acceptance research so far, although their perspectives are mandatory in order to do justice to needs of care and care itself in professional care contexts. Single studies focused on caregivers as potential users and on their perceived concerns regarding in-home monitoring technologies (Larizza et al., 2014). Other studies concentrated on requirements and perception of AAL technology usage as well as the effectiveness of different technologies, and deriving of guidelines for design and implementation in the context of professional care environments (López et al., 2015; Mortenson et al., 2013).

Although those previous results showed a general positive attitude towards AAL technologies, another comparative study revealed a more critical and restraint attitude of professional caregivers towards AAL technologies compared to disabled participants, relatives of disabled persons, and "not"-experienced (in terms of professional expertise or in terms of personal affliction) participants (van Heek et al., 2017a). This might serve as a starting point and explanation why AAL technologies are not widely used in professional care contexts. Hence, it is of great importance to investigate the perceptions, wishes, and needs of this specific user group in depth. To understand the emerging negative attitude of professional caregivers and the trade-off between acknowledged benefits and existing perceived barriers, it is necessary to investigate the acceptance of AAL technologies with a specific and detailed focus on these users and their usage environments.

For investigating the acceptance of assisting ICT, well-known and widely spread acceptance models such as TAM, UTAUT, and their adapted versions were urgently used in the past years. Against the background of increasing usage requirements in the context of care, the existing models of technology acceptance are not sufficient among others due to the sensible usage context of care, the models' view of acceptance as static technology assessment, and leaving apart user factors as well as trade-offs between simultaneously existing benefits and barriers (Ziefle & Jakobs, 2010).

Therefore, we used interviews specifically tailored to professional caregivers in a first step in order to identify challenges in care and focus on perceived benefits as well as perceived barriers of AAL technology usage. Further, we aimed for an identification of what technology is exactly allowed to do and not to do by professional caregivers. On this basis, we conceptualized an online questionnaire tailored to professional caregivers needs and wishes and ensured that all relevant aspects (for this specific user group) can be quantified.

# 3 METHOD

In this section, the research design is presented starting with the research questions and aims of the current study. Afterwards, the empirical design of the quantitative study and the sample's characteristics are detailed. Our study aimed for an investigation of professional caregivers' acceptance of AAL technologies in professional care contexts including the following research questions:

1. How do professional caregivers evaluate AAL technologies and potential benefits as well as barriers? (*RQ 1*)
2. Which data can be gathered, which technologies can be used to gather data, and how is data access and storage duration evaluated? (*RQ 2*)
3. Do user diversity characteristics impact the acceptance and AAL technology evaluation dimensions (benefits, barriers, technologies, data, data access, storage duration)? (*RQ 3*)

## 3.1 Empirical Design

The questionnaire items were developed based on the findings of previous interview studies. The first part of the questionnaire addressed demographic characteristics such as age, gender, education, duration of professional experience, and care sector (i.e. geriatric care, nursing care, care/support of disabled people). In the next part, the participants were asked to evaluate their technical self-efficacy (using four items, $\alpha = .884$; Beier, 1999), their needs for privacy (using six items, $\alpha = .833$; Xu et al., 2008; Morton, 2013), and their interpersonal trust (using three items, $\alpha$ = .793; McKnight et al., 2002).

For ensuring that all participants pertain to the same baseline referred to the evaluation of AAL technology, a scenario was designed as a very personal everyday working situation wherein the participants should imagine that an AAL system was integrated in their professional working environment. As technologies of the system, room sensors, ultrasonic sensors, microphones, and video cameras were introduced and their range of functions and possibilities within the AAL system were explained (e.g., alarms (emergencies, falls), automatic opening and closing of doors and windows, reminders, etc.).

Afterwards, the participants were asked to evaluated potential benefits of the described AAL system's usage within their professional working environment (using 14 items, $\alpha$ = .923; based on previous interview studies' results). Further, the participants also assessed potential barriers (using 17 items; $\alpha$ = .861; also based on previous interview studies' results). In a next part, the participants should indicate whether they agreed with gathering different types of data (using 14 items (data types), $\alpha$ = .856; based on necessary information to realize technical functions).

Then, the participants were asked to evaluate different technologies to gather data (using 12 items, $\alpha$ = .892; based on technical configurations of AAL systems). To evaluate the acceptance of the AAL system, the participants evaluated six different statements ($\alpha$ = .932; e.g., "I find the described AAL system useful"). All described items had to be evaluated on six-point Likert scales (1 = *min*: "I strongly disagree"; 6 = *max*: "I strongly agree") and are presented in section 4.

Finally, the participants were given opportunity to reason their opinions on an optional basis and to provide their feedback concerning the study. Completing the questionnaire took, on average, 20 minutes. Data was collected online in Germany. Participants were recruited in online networks as well as by personal and project contact to care institutions. Overall, the questionnaire was made available for 3 months in spring and summer 2017.

### 3.2 Sample Description

A total of 287 participants volunteered to participate in our questionnaire study, which was partly acquired by personal and by direct contact to professional care institutions. Since only complete data sets could be used for statistical analyses, a sample of $n$=174 remained. The participants were, on average, 36.3 years old ($SD$ = 11.2; $min$ = 19; $max$ = 68) and predominantly female (74.7%) (25.3% male). Most of the participants indicated a completed apprenticeship (42.5%) as their highest educational level. Further, each 23.0% reported to hold a university degree and a university entrance diploma. 7.5% indicated to hold a secondary school certificate, while 4.0% reported other certificates.

All participants worked or have worked as professional caregivers: 25.9% ($n$ = 45) in geriatric care, 21.3% ($n$ = 37) in nursing care, and 52.9% ($n$ = 92) in care and support of disabled people. On average, the caregivers have long-term professional experience: 43.5% ($n$ = 74) more than 10 years, 41.8% ($n$ = 71) between 3 and 10 years, and only 14.7% (n = 25) have less than 3 years professional experience.

Referring to attitudinal variables, the participants reported to have on average a middle technical self-efficacy ($M$ = 3.4; $SD$ = 0.7; $min$ = 1; $max$ = 6) and also a middle interpersonal trust ($M$ = 3.5; $SD$ = 0.8; $min$ = 1; $max$ = 6). The participants' needs for privacy and data security were on average positive ($M$ = 4.2; $SD$ = 0.9; $min$ = 1; $max$ = 6).

## 4 RESULTS

Prior to descriptive and inference analyses, item analyses were calculated to ensure measurement quality, while a Cronbach's alpha > 0.7 indicated a satisfying internal consistency of the scales. Data was analyzed descriptively, by linear regression analyses and, with respect to user diversity effects, by correlation and linear regression analysis. The level of significance was set at 5%.

First, the results were presented descriptively for the perception of benefits and barriers as well as the participants' evaluation of different technologies, gathered data, data access, and data storage. In a second step, the results of a linear regression analysis are presented to analyse which aspect affects the professional caregivers' acceptance of AAL technologies most. Afterwards, the results are analysed regarding influences of user diversity characteristics.

### 4.1 General Perception of AAL

This section presents the results concerning perceived benefits and barriers of AAL system usage, desired applied technologies and data that could be gathered as well as acceptance of different AAL technology systems. Thereby, the results initially refer to the whole sample of caregivers investigating *RQ 1* and *RQ 2*.

### 4.1.1 Perceived Benefits and Barriers (*RQ 1*)

Figure 1 presents the evaluation of perceived **benefits** of an AAL system's usage. *Fast Assistance in emergencies* (*M* = 4.6; *SD* = 1.2) was perceived as the most important benefit, followed by *increase in safety for inhabitants* (*M* = 4.3; *SD* = 1.2). Potential benefits with regard to care staff (*higher control in everyday working life* (*M* = 4.0; *SD* = 1.5), *relief in documentation of care* (*M* = 3.9; *SD* = 1.4), *simplified proof of rendered care* (*M* = 3.9; *SD* = 1.4), *relief in everyday working life* (*M* = 3.8; *SD* = 1.4)) were rated only slightly positively. Other potential benefits such as *relief in everyday life* (*M* = 3.8 *SD* = 1.3), *extension of autonomy* (*M* = 3.7; *SD* = 1.4), or *reduction of dependency* (*M* = 3.5; *SD* = 1.4) for inhabitants were also rated only slightly positive or almost neutrally. The two rather care staff-related aspects *lower fear to be able to do own mistakes* (*M* = 2.9; *SD* = 1.5) and *measure against crisis in care* (*M* = 2.9; *SD* = 1.6) were rated slightly negatively and were thus not perceived as benefits of AAL technologies in professional care contexts.

In contrast to the diverse evaluation of benefits (with accepted and rejected potential benefits), none of the potential **barriers** was rejected (see Figure 2). Therefore, almost all aspects were perceived as solid barriers of AAL technology usage in professional care contexts. In detail, items related with privacy and data security (e.g., *invasion in privacy* (*M* = 5.2; *SD* = 1.0)*, data abuse by third parties* (*M* = 4.8; *SD* = 1.2)*, recording of data* (*M* = 4.7; *SD* = 1.3)) or with a perceived surveillance (i.e. *surveillance by technology* (*M* = 5.0; *SD* = 1.1), *control by supervisors* (*M* = 4.9; *SD* = 1.2), *control by colleagues* (*M* = 4.6; *SD* = 1.3)) were rated highest and represent relevant barriers. Further, other aspects such as *fear of isolation* (*M* = 4.1; *SD* = 1.4), *missing trust in technical functionality* (*M* = 3.9; *SD* = 1.4), or *interruption of routines* (*M* = 3.9; *SD* = 1.3) were evaluated slightly positively. In contrast, *handling seems to be too complex* (*M* = 3.5; *SD* = 1.3) and *confrontation with new technology* (*M* = 3.4; *SD* = 1.4) were rated neutrally and thus, those aspects were not perceived as notably relevant barriers of AAL technology usage.

### 4.1.2 Data and Specific Technologies (*RQ 2*)

Besides perceived benefits and barriers of AAL technology usage in professional care contexts, the participants were also asked for which data should be allowed to be gathered (Figure 3) and which specific technology should be used to gather data (Figure 4) to answer *RQ 2*.

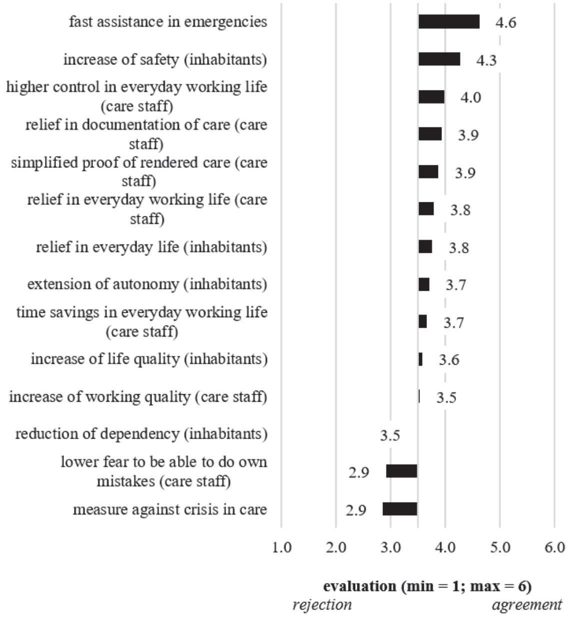


Figure 1: Perceived benefits of AAL technology usage.

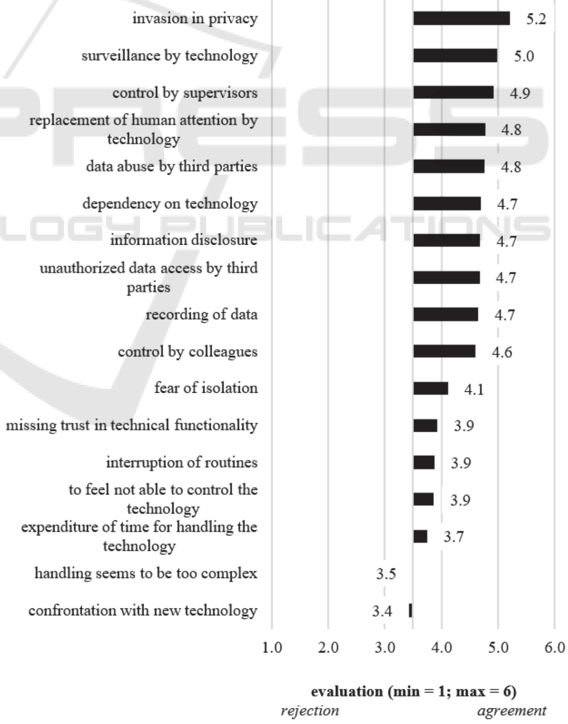


Figure 2: Perceived barriers of AAL technology usage.

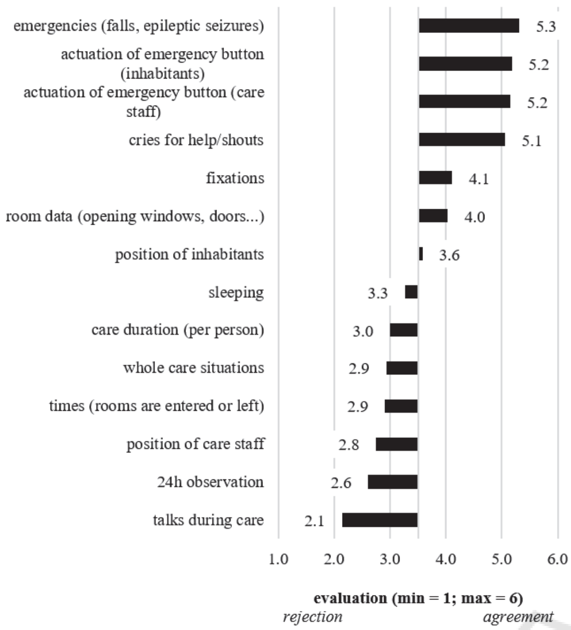


Figure 3: Evaluation of type of gathered data.

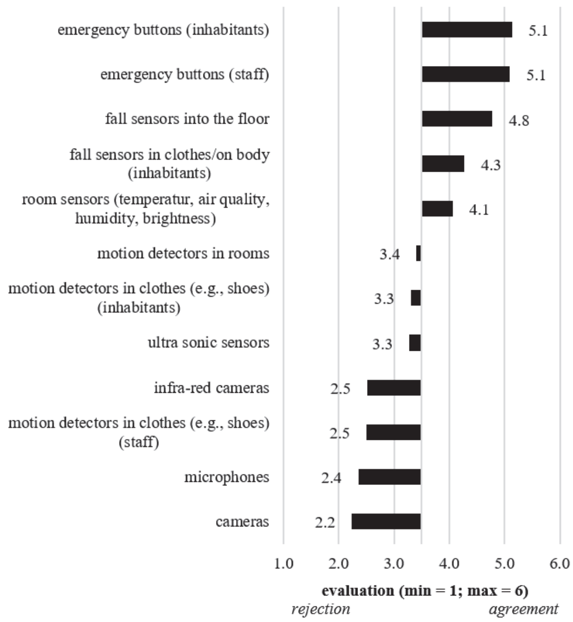


Figure 4: Evaluation of technologies used to gather data.

To **gather data** related with emergency situations (*emergencies (falls epileptic seizures)* (*M* = 5.3; *SD* = 0.9), *actuation of emergency buttons* (*care staff*: *M* = 5.2; *SD* = 1.0; *inhabitants: M* = 5.2; *SD* = 1.0), and *cries for help/support M* = 5.2; *SD* = 1.0) was clearly accepted. Data about *fixations* (*M* = 4.1; *SD* = 1.6) and *rooms (opening windows, doors, ...)* (*M* = 4.0; *SD* = 1.6) were also allowed to be gathered. Further, gathering the *position of inhabitants* (*M* = 3.6; *SD* = 1.4) was evaluated neutrally, while the *position of care staff* (*M* = 2.8; *SD* = 1.5) was rather rejected. Data about *sleeping* (*M* = 3.3; *SD* = 1.5), *care duration* (*M* = 3.0; *SD* = 1.6), *whole care situations* (*M* = 2.9; *SD* = 1.6), and *times (rooms are entered or left)* (*M* = 2.9; *SD* = 1.5) should also not be gathered due to rather negative values. In contrast, to gather data concerning a *24h observation* (*M* = 2.6; *SD* = 1.6) and regarding *talks during care* (*M* = 2.1; *SD* = 1.4) was clearly rated negatively and was thus not accepted.

Like the diverse evaluation of the type of gathered data, the specific **technologies** that should be used to gather data were also assessed quite differently (Figure 4). The use of *emergency buttons* (*inhabitants*: *M* = 5.1; *SD* = 1.1; *care staff: M* = 5.1; *SD* = 1.2) and *fall sensors into the floor* (*M* = 4.8; *SD* = 1.4) were clearly accepted. Further, *fall sensors in clothes on body of inhabitants* (*M* = 4.3; *SD* = 1.5) and *room sensors* (*M* = 4.1; *SD* = 1.6) were rated positively. To use *motion detectors* (*in rooms: M* = 3.4; *SD* = 1.6; *in clothes of inhabitants: M* = 3.3; *SD* = 1.6) as well as *ultrasonic sensors* (*M* = 3.3; *SD* = 1.5) was marginally rejected. In contrast, *infra-red cameras* (*M* = 2.5; *SD* = 1.4), *motion detectors in clothes of care staff* (*M* = 2.5; *SD* = 1.5), *microphones* (*M* = 2.4; *SD* = 1.4), and *cameras* (*M* = 2.2; *SD* = 1.3) were evaluated clearly negatively. Therefore, those technologies were not accepted as technologies to gather data in professional care contexts.

As a further aspect, the participants assessed the storage duration and data access after data was gathered (Figure 5). Here, only the most striking descriptive results are reported.

Concerning **data access**, *room data* was the own data type that received slightly positive values and data access for all supervisors (*M* = 3.7; *SD* = 1.7), direct supervisors (*M* = 3.9; *SD* = 1.6), and colleagues (*M* = 4.0; *SD* = 1.6) was at least tolerated. In contrast, the negative evaluations showed that *position data, audio data*, and *video data* should neither be accessible for all supervisors, direct supervisors, nor colleagues. Regarding **storage duration,** the comparatively positive values showed that all data types should *only be allowed to be evaluated for the moment* (video: *M* = 3.8; *SD* = 1.7; audio: *M* = 3.8; *SD* = 1.8; position: *M* = 4.0; *SD* = 1.6; room: *M* = 4.1; *SD* = 1.5). *Storage on a daily basis* (video: *M* = 2.6; *SD* = 1.5; audio: *M* = 2.6; *SD* = 1.6; position: *M* = 2.8; *SD* = 1.5) and in particular *long-term storage* (video: *M* = 1.9; *SD* = 1.2; audio: *M* = 1.8; *SD* = 1.1; position: *M* = 2.1; *SD* = 1.3) were rejected for all data types except of *room data* that received only almost neutral values for *storage on a daily basis* (*M* = 3.7; *SD* = 1.7) as well as *long-term storage* (*M* = 3.4; *SD* = 1.8). Thus, storage was most likely tolerated with regard to *room data*.

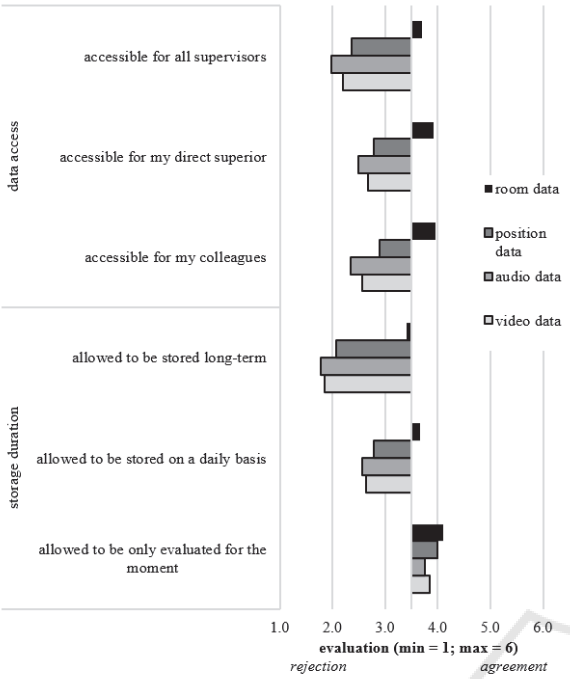


Figure 5: Evaluation of storage duration and data access for different data types.

### 4.1.3 Acceptance of AAL technologies

Overall, the acceptance of the mentioned AAL technologies was evaluated rather neutrally ($M = 3.6$; $SD = 1.3$). Comparatively, *a system consisting only of room sensors* ($M = 4.0$; $SD = 1.5$) received the highest evaluation, while a *system consisting of all mentioned technologies except of a camera* was assessed worst ($M = 2.9$; $SD = 1.4$).

In order to analyze, which of the descriptively presented factors influences the acceptance of AAL technologies most, a step-wise linear regression analysis was conducted: here, the acceptance of AAL technology usage was calculated as dependent variable, while perceived benefits, perceived barriers, data that is allowed to be gathered, specific type of technology, data access, and storage duration represented the independent variables. The calculation revealed four significant models. The first model predicted 59.1% (adj. $r^2 = .591$) variance of AAL technology acceptance and was based on the *specific technology* that is used to gather data. Thus, the acceptance of AAL technology usage depends clearly on the specific technologies that are used and integrated in the system. The second model additionally contained *perceived benefits* and explained +8.5% (adj. $r^2 = .676$) variance of AAL technology acceptance. The third model explained +3.2% (adj. $r^2 = .708$) variance and was based on the specific technology, perceived benefits, and additionally on the *type of gathered data*. The fourth and final model explained +2.2% (adj. $r^2 = .730$) variance of AAL technology acceptance and contained besides perceived benefits, specific technology, type of gathered data, also *perceived barriers*. The other two integrated dimensions *data access* and *storage duration* were not part of the regression models and did not influence the acceptance of AAL technologies significantly. Figure 6 illustrates the final regression model and displays the regression coefficient $\beta$ for all independent variables.

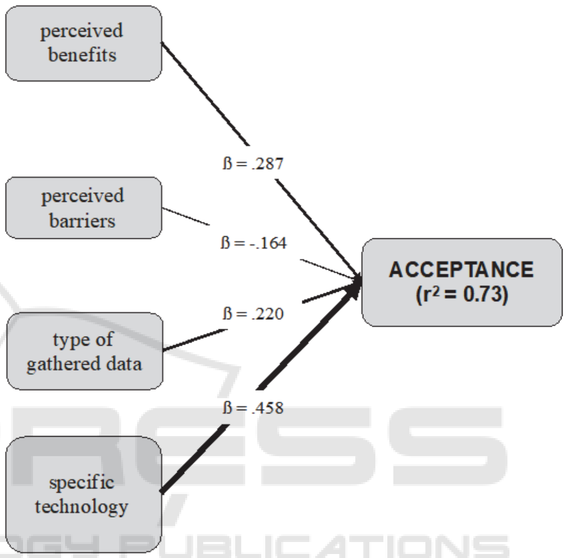


Figure 6: Final regression model based on significantly influencing variables.

## 4.2 Impact of Individual Characteristics (*RQ 3*)

So far, the results referring to the whole sample of caregivers have been presented. As user diversity plays an important role in the acceptance of medical and assistive technologies (see section 2.2), the results are further analyzed concerning impacts of demographic and attitudinal characteristics of the participants to answer *RQ 3*.

First, correlation analyses were conducted in order to find out which demographic and attitudinal characteristics are relevant for the acceptance of AAL technologies (Figure 7). Starting with *demographic characteristics*, the results revealed only single correlations with the dimensions of AAL technology usage: *Age* was not related at all with one of the other dimensions. *Gender* correlated only slightly with perceived barriers of AAL technology usage ($\rho = -.156$; $p < .05$) and women showed a

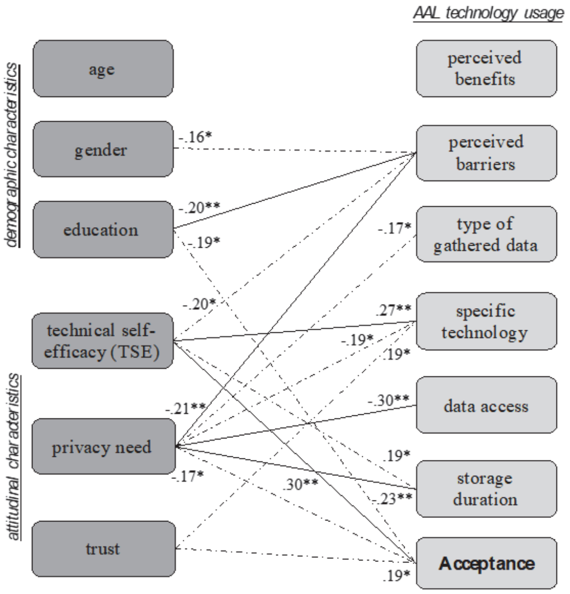

Figure 7: Results of correlation analysis: user diversity impacts (dotted line: p<.05; solid line: p<.01).

slightly higher evaluation of perceived barriers than men. *Education* was slightly related with perceived barriers ($\rho$ = -.202; $p$ < .01) and acceptance of AAL technologies ($\rho$ = .196; $p$ < .05). Subsequently conducted multivariate variance analyses, revealed no significant impact of the demographic characteristics on the AAL technology usage dimensions.

Referring to *attitudinal characteristics*, the results revealed more striking relationships. For interpersonal *trust*, there were indeed only single, slight correlations with the evaluation of specific technologies ($\rho$ = .189; $p$ < .05) and acceptance of AAL technologies ($\rho$ = .186; $p$ < .05). In contrast, the results showed numerous and partly also stronger correlations for the two attitudinal variables *privacy need* and *technical self-efficacy (TSE).* The strongest correlations of *privacy need* referred to perceived barriers ($\rho$ = .209; $p$ < .01), data access ($\rho$ = -.301; $p$ < .01), and storage duration ($\rho$ = -.228; $p$ < .01) indicating that participants with higher needs for privacy showed higher evaluations of perceived barriers and a more negative attitude towards data access for other people and a long-term data storage. Concerning *technical self-efficacy*, the strongest relationships referred to the evaluation of specific technologies ($\rho$ = .274; $p$ < .01) and acceptance of AAL technology usage ($\rho$ = .299; $p$ < .01) indicating that participants with a higher technical self-efficacy showed a more positive attitude towards specific technologies and a higher acceptance of AAL technologies.

To investigate the impact of user diversity factors in depth, the attitudinal variables were also analyzed in multivariate variance analyses. For trust, the results revealed no significant impact on the AAL technology usage dimensions. Concerning two groups with different privacy needs, the analysis confirmed that data access ($F(1,158)$=7.076; $p$ < .01) and storage duration ($F(1,158)$=6.359; $p$ < .05) are considered as significantly more critical by people with high privacy needs ($M_{access}$ = 2.7, $SD_{access}$ = 0.9; $M_{storage}$ = 2.9, $SD_{storage}$ = 0.9) compared to people with lower privacy needs ($M_{access}$ = 3.2, $SD_{access}$ = 1.1; $M_{storage}$ = 3.3; $SD_{storage}$ = 0.7).

Likewise, two groups with a different technical self-efficacy (TSE) differed significantly regarding perceived barriers ($F(3,149)$=7.708; $p$ < .01), the evaluation of specific technologies ($F(1,149)$=6.051; $p$ < .05), and acceptance of AAL technologies ($F(1,149)$=6.564; $p$ < .01). The results revealed that people with a higher TSE ($M$ = 4.1; $SD$ = 0.7) evaluated perceived barriers significantly lower than people with a lower TSE ($M$ = 4.5; $SD$ = 0.7). Further, the results confirmed that people with a higher TSE ($M_{tech}$ = 3.8, $SD_{tech}$ = 1.1; $M_{accept}$ = 4.0; $SD_{accept}$ = 1.3) had a more positive attitude towards the specific technologies and showed also a higher acceptance of AAL technologies than people with a lower TSE ($M_{tech}$ = 3.4, $SD_{tech}$ = 0.9; $M_{accept}$ = 3.4; $SD_{accept}$ = 1.2). These results show that user groups with different needs for privacy and a different technical self-efficacy differed with regard to the evaluation of AAL technology usage dimensions. Thus, it was important to find out, whether different dimensions influence the acceptance of AAL technologies for the TSE and privacy need groups.

For this purpose, we again conducted regression analyses separately for the diverse groups. Here, only the final regression models are reported (Table 1 & 2). Starting with *privacy needs* (Table 1), the final model for participants with *low privacy needs* explained 61.4% variance of AAL acceptance based on the evaluation of specific technologies and perceived benefits of AAL technology usage. In contrast, the final regression model for participants with *high needs for privacy* explained 76.6% of the variance of AAL technology acceptance based on the four dimensions: specific technologies, perceived benefits, type of data, and perceived barriers.

A similar pattern occurred for the two *technical self-efficacy (TSE) groups* (Table 2). Here, the regression model for people with a high TSE explained 73.4% variance of AAL acceptance based on the dimensions technology and perceived benefits.

Table 1: Final regression model for participants with low and high needs for privacy.

| Privacy | Dimension | B | SE B | β | T |
|---|---|---|---|---|---|
| *high needs* | technologies | .640 | .104 | .458 | 6.145 |
| | benefits | .319 | .079 | .236 | 4.019 |
| | type of data | .448 | .112 | .282 | 4.013 |
| | barriers | -.279 | .099 | -.155 | -2.836 |
| *low needs* | technology | .603 | .145 | .504 | 4.148 |
| | benefits | .364 | .089 | .269 | 3.988 |

However, the regression model for the low TSE group explained 70.6% variance of AAL technology acceptance and - similar to the high needs for privacy group – based on the four dimensions: specific technologies, perceived barriers, type of data, and perceived benefits.

Table 2: Final regression model for participants with a low and a high technical self-efficacy (TSE).

| TSE | Dimension | B | SE B | β | T |
|---|---|---|---|---|---|
| *low* | technologies | .716 | .131 | .490 | 5.470 |
| | barriers | -.333 | .125 | -.179 | -2.660 |
| | type of data | .389 | .126 | .247 | 3.087 |
| | benefits | .251 | .101 | .197 | 2.494 |
| *high* | technology | .780 | .094 | .651 | 8.274 |
| | benefits | .606 | .112 | .425 | 5.400 |

# 5 DISCUSSION

This study revealed insights into caregivers' perspectives on the acceptance of specific AAL technologies in professional care environments. As professional caregivers play a decisive role for the acceptance of AAL technologies in professional care contexts, we aimed for a detailed analysis of the needs and wishes of this specific stakeholder group. The results provide valuable insights into acceptance-decisive factors of AAL technologies in professional care contexts and should be taken into account for the development, design, and configuration of AAL technologies.

## 5.1 AAL System Acceptance (*RQ 1&2*)

The caregivers' evaluations of AAL technology acceptance, perceived benefits, and barriers (see *RQ 1*) differ clearly from previous research results concerning AAL technology acceptance. In contrast to a general positive evaluation of AAL technologies found in numerous past studies (e.g., Beringer et al., 2011; Gövercin et al., 2016), this study's professional caregivers uncover a very restrained attitude towards AAL technologies and show neutral acceptance evaluations, if at all. As implied in a preceding study (van Heek et al., 2017a), the present study confirms that professional caregivers are much more critical with regard to the integration of AAL technologies in their (professional) everyday life than other stakeholders.

On the one hand, this is expressed by low agreements of potential benefits. Except of a faster assistance in emergencies, all benefits are evaluated only with rather positive or rather negative i.e. primarily neutral values. Thus, potential benefits (e.g., measure against care crisis) are not perceived as real benefits. This may be due to the applied methodology of the scenario-based approach: as previous studies proved that hands-on experience with AAL technologies lead to more positive perceptions of usage motives (Wilkowska et al., 2015), it can be assumed that professional caregivers would also evaluated AAL technologies differently if they would have the chance trying to use those technologies in their professional everyday life.

On the other hand, the more negative and critical attitude of professional caregivers is expressed by high agreements of barriers: none potential barrier is rejected and thus, all potential barriers are perceived as real barriers and severe drawbacks. This pattern contrasts clearly to previous research results showing a much lower reluctance to AAL systems and a lower confirmation to the perceived barriers. (e.g., van Heek et al., 2017a,b). Within the perceived barriers especially the aspects of a potential invasion of privacy, data security concerns, and a feeling of surveillance are of importance for professional caregivers. It is a noteworthy finding that the nature of the seen barriers in the professional caregivers' perspective center around their own professional person. The most severe concern is not to be tracked or controlled. The patients, the caretakers, for which caregivers are responsible and which could seriously profit from AAL Systems are not taken into account.

Further, the study revealed detailed novel insights into the perceptions of professional caregivers respecting their perspective which data should be allowed to be gathered and which technology should be used to gather data, if at all (*RQ 2*). The results show clearly that *only* emergency-related data is allowed to be gathered. All other data types are rejected or only just tolerated. This contrasts significantly to the functions caregivers want AAL technologies to undertake (as reported in open comment fields and interviews), for which gathering different data types is factually necessary. The evaluation of technologies that should be used for data collection, shows similar results: the professional caregivers only indicate to accept technologies that are partly already existing (e.g., emergency buttons) or gather only static, binary data (e.g., room sensors). More complex technologies with a potential higher privacy invasion (e.g., cameras, microphones) are rejected. This is in line with previous research results (e.g., Himmel et al., 2016) and illustrates the opposition between the desired technical functionality (that could support them in caring) and the admitted data and technology configurations. The evaluation of data storage and data access confirms the negative attitude and evaluation of perceived barriers, because nearly nobody is really allowed to access gathered data and data should only be processed - not stored.

As data is not needed to be stored long-term for most of the functions AAL technologies could undertake, targeted communication strategies focusing on handling of data (e.g., only processing, not storage) could may help to dismantle perceived barriers and especially caveats concerning privacy and data security.

## 5.2 Diversity of Users Matters (*RQ 3*)

The integration of user diversity factors into the analysis of AAL technology acceptance shows that demographic characteristics of the professional caregivers are not decisive and did not influence the caregivers' acceptance of AAL technologies (see *RQ 3*). In contrast, the results illustrate that attitudinal characteristics are more relevant and influence the perception of AAL technologies.

Technical self-efficacy as well as the caregivers' need for privacy impact the acceptance and perceptions of AAL technologies significantly. Similar to previous studies (e.g., Ziefle & Schaar, 2010), people with a higher technical self-efficacy show a higher acceptance of AAL technologies which is influenced by the type of technology and perceived benefits. In contrast, people with a lower technical self-efficacy are more restrained concerning the acceptance of AAL technology. A low technical self-efficacy affects the evaluation of the type of technology and perceived benefits but additionally also the type of gathered data as well as perceived barriers. A similar pattern was revealed for persons with different needs for privacy: people with low needs for privacy show a considerably higher AAL technology acceptance, influenced by type of technology and perceived benefits. And vice versa: people with high needs for privacy indicate a lower acceptance influenced by the evaluation of type of technology, perceived benefits, perceived barriers, and type of data.

Summarizing, professional caregivers' technical expertise and need for privacy contribute to a different emphasis referring to the perception of barriers and caveats (i.e. data gathering, storage, access, and privacy). This confirms that especially the way AAL technologies handle data should be focused in future studies and integrated in communication referring to AAL technologies in professional environments.

## 5.3 Limitations and Future Research

Our empirical approach provided valuable insights into AAL technology acceptance of professional caregivers in professional care contexts as it focused on evaluations of specific benefits and barriers as well as concrete data and technology configurations. Nevertheless, there are some limitations concerning the applied method and sample that should be considered in future approaches.

The present study was a first scenario-based approach focusing on professional caregivers' acceptance of AAL technologies, their perceptions of benefits and barriers as well as specifically on their evaluations of technologies and data configurations. As already mentioned, the applied methodological approach was based on a scenario and thus, on a fictional and not on a real AAL system, what probably influences the evaluations and may lead to an underestimation of potential benefits and an overestimation of potential barriers (Wilkowska et al., 2015). Thus, we aim for hands-on evaluations of AAL technologies in future studies focusing on professional caregivers and respectively usage of AAL technologies in professional care environments.

As a first aspect referring to the sample, the sample size as well as balance of demographic characteristics was sufficient - in particular, referred to the condition that only professional caregivers were acquired. The higher proportion of female participants in the sample represents and fits to the higher proportion of women working in care institutions (Simonazzi, 2008). An interesting aspect for future studies is the investigation of potential care sector influences (geriatric care, nursing care, care of disabled people) on the acceptance and perception of AAL technologies in professional contexts due to different challenges and processes in the respective sectors. Finally, this study focused German participants and thus, it represents the perspective of professional caregivers of one specific country with a specific health care system. We assume that the acceptance of AAL technologies differs with regard to different countries, their cultures and their specific healthcare systems. Therefore, we aim for conducting our approach in other countries to be able to directly compare AAL acceptance depending on different countries and cultures.

## ACKNOWLEDGEMENTS

The authors thank all participants for their openness to share opinions on innovative technologies. Furthermore, the authors want to thank Hannah Fahnenstich for research assistance. This work was funded by the German Federal Ministry of Education and Research project Whistle (16SV7530).

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