Privacy Concerns and the Acceptance of Technologies for Aging in Place

Eva-Maria Schomakers(✉) and Martina Ziefle

Human-Computer Interaction Center, RWTH Aachen University,
Campus-Boulevard 57, 52074 Aachen, Germany
{schomakers,ziefle}@comm.rwth-aachen.de

Abstract. Technologies to support older adults in Aging in Place have the potential to address the challenges that aging populations pose on healthcare systems. Technology acceptance and the way individuals' privacy concerns are met are decisive determinants for their success. To understand the nature and impact of privacy concerns, two empirical studies were conducted. In focus groups, privacy concerns and conditions are identified. Participants worry especially about illicit information abuse, but also about feelings of surveillance and loss of control. In a subsequent questionnaire study, privacy concerns and their impact on acceptance are quantified (n = 97). Privacy concerns are not as pronounced as are benefits of technology use and show less impact on acceptance. Differences between a fall detection system and remote monitoring of vital parameters are detected. Older adults are less positive towards care-assistive technologies than younger adults. Findings contribute to an understanding on how technologies should be designed to match the desires of potential users.

Keywords: Technology acceptance · Privacy concerns · Aging · Technologies for Aging in Place · Ambient Assisted Living

1 Introduction

The proportion of senior citizens in Europe will increase from 19% (2015) to approximately 28% in 2050 (Eurostat 2015). The baby boom generation born in the 1960s will soon reach retirement age. Life expectancy is still increasing. 11% of the European population will be older than 80 years in 2050.

These demographic developments have already become reality in many regions of the world and are even more advanced in some countries, for example in Germany (Eurostat 2015). The aging populations constitute an enormous challenge for the welfare state, society, and healthcare systems. Other societal trends amplify these problems: almost every third senior citizen lives alone, only 8% live under one roof with younger generations, and more women are working. Correspondingly, informal care by family caregivers becomes more complex or inapplicable. Still, most senior citizens prefer to live in their own home as long

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as possible, even when everyday chores become harder to cope with (Benefield and Holtzclaw 2014). *Aging in Place* can contribute to a sense of independence, autonomy, and social connectedness, providing both, psychological and emotional benefits (Wiles et al. 2012). Aging in Place is not only favored by many older adults but also by policy makers and health providers as healthcare costs and resources can be reduced (Graybill et al. 2014). Technologies can support and assist older adults in Aging in Place and support their formal and informal caregivers. With improving independence, safety, social contacts, and quality of care, *Technologies for Aging in Place* can contribute to a high quality of life in older age and prolong the stay of older adults in dignity in their own four walls (Siegel and Dorner 2017).

In the last decades, much research effort has been put into the development of technologies for Aging in Place (Van Grootven and van Achterberg 2016). But these technologies will only then be successful and exploit their full potential, when they suit the needs of the potential users and the respective contexts, in which technology is used. Technology acceptance is decisive, but is a great challenge for technologies for Aging in Place which is torn between multiple obstacles. First, the target group of older adults is heterogeneous regarding the use of novel technologies (Czaja et al. 2006). Secondly, the home has an emotional meaning for us and also for older adults who spent much time and activities in their own four walls. Altering this place of life may cause resentments (Mortenson et al. 2016). Finally, most technologies for Aging in Place are based on the collection of sensitive and intimate information from the body or the home of the users. Accordingly, privacy concerns are a crucial barrier for acceptance (Yusif et al. 2016).

The focus in this study is put on privacy concerns as a key barrier to acceptance within the context of the home and older adults as potential users.

2 Related Work

2.1 Aging in Place and Technology Support

The concept Aging in Place can be described as the provision of appropriate services and assistance for older adults to remain living in their current home or community in relative independence (Vanleerberghe et al. 2017). Various terms for similar technologies are used: for example, smart homes for the elderly, Ambient Intelligence, Ambient Assisted Living or assistive ICT. In Europe, the terms *Ambient Assisted Living*, and *Active and Assisted Living* are popular based on the Ambient Assisted Living (AAL) Joint Programme that was established by the European Union to develop appropriate technology solutions (Ambient Assisted Living Joint Programme 2012). In this publication, the wider term of *technologies for Aging in Place* is used as umbrella term to include all technologies designed to support older adults in Aging in Place in the areas of safety and security, therapy support and remote monitoring, home automation, support of daily chores as well as telemedicine and social communication. These include stand-alone devices, interconnected systems, robots, and applications for ICT

devices. Popular examples for such technologies are, e.g., fall detection systems, vital parameter monitoring, medication reminders, video-mediated communication, and automated door and window openers (Blackman et al. 2016).

The goal of Aging in Place is to prevent or delay moves to dependent facilities and thereby meet the desire of most older adults to stay home. Aging in Place can also counteract the financial challenges of the aging population, as the costs are much lower than the costs of institutionalization (Graybill et al. 2014). Aging in Place can thus contribute to a high quality of life, giving a sense of independence and autonomy as well as emotional and social connection to the community and spaces (Biermann et al. 2018; Wiles et al. 2012). For older adults, the home is the major place not only for retreat and privacy but also for many activities and social relationships. Home is an extension of the self and connects to self-identity (Himmel and Ziefle 2016; Oswal and Wahl 2005).

2.2 Technology Acceptance

Still, the adoption of technologies for Aging in Place in the population is slower than anticipated (Hallewell Haslwanter and Fitzpatrick 2016). One key aspect for the diffusion of such technologies is the technology acceptance (Lee and Coughlin 2014). The research stream of technology acceptance explains why users use technologies and models the determinants of acceptance. The wide range of factors and determinants on acceptance can be structured into three levels: (1) the technology itself, (2) the users and their characteristics, and (3) environmental and contextual aspects. Popular models of technology acceptance, for example TAM (Technology Acceptance Model, Davis (1989)) and UTAUT (Unified Theory of Acceptance and Use of Technology, Venkatesh et al. (2003)), include attitudes and beliefs, social influence and demographic user factors to predict acceptance. Acceptance is operationalized as the intention or willingness to use a technology, which is modelled as the predictor of use behavior.

Regarding older adults and technologies for Aging in Place, these models are not sufficient to explain the diversity of aspects that shape the intention to adopt these technologies. Age, specifics of the context, as well as privacy concerns need to be additionally considered.

Age: The group of older adults is everything but homogeneous. Physical and cognitive changes in aging are highly individual and influence the capabilities to interact with technologies as well as the willingness to use them, creating a large diversity (Arning and Ziefle 2009). Additionally, the experiences with technologies during upbringing and working life influence familiarity and expectations towards technologies (Sackmann and Winkler 2013). The technology generations of today's older adults learned strategies of use and interactions with technologies that do not fit modern technologies. Additionally, the perspective of women needs to be considered in these age groups due to the still existing differences with regard to (professional) experiences with technologies and the simultaneously higher proportion of older women. Contrary to many prejudices, many

older adults are willing to try new technologies, but these need to match their specific needs and capabilities (Czaja et al. 2006). Still, on average, technology adoption by today's older adults is limited, which is intensified with poor health status, education, and older age (Heart and Kalderon 2013).

Context: Most technology acceptance models were developed for the organizational or consumer electronics context. They have been adapted to other contexts, but the transferability has rarely been validated (Arning and Ziefle 2009). Technologies for Aging in Place act within the intersection of home and health. The home is not just a physical space to live but a meaningful place that is the major focus of older adults, especially when frailty increases (Mortenson et al. 2016). The home means a refuge for privacy and intimacy, social connectedness as well as identity and emotion (Oswal and Wahl 2005). Technologies for aging in place may intrude, altering perceptions of home and changing routines (Mortenson et al. 2016). At the same time, many operate in a health context which is very intimate. The perception of need for technological support is a decisive determinant for the acceptance, especially by older adults (Czaja et al. 2013). Many older adults do not see themselves in need of this assistance. The availability of alternatives, e.g., support by family members, and habits of compensating or just accepting problems, diminish the perception of need for oneself (Schomakers et al. 2018).

Privacy: Technologies for Aging in Place, especially monitoring technologies, utilize many sensors and collect, analyze and transmit intimate data from the home, behavior, and health of the user. Correspondingly, privacy concerns are a major barrier to their acceptance and use (Yusif et al. 2016). Users trade off perceived barriers, particularly privacy concerns, against benefits of the technology use for them to decide on the overall acceptance (van Heek et al. 2017). This *privacy calculus* has been studied in various contexts including health and assistive technologies (Ermakova et al. 2014; Halbach et al. 2018).

2.3 Privacy Concerns

The perceived essence of privacy is the sense of being in control. Privacy can be categorized into the control over access to the physical self (*physical privacy*), social interaction and communication (*social privacy*), thoughts and feelings (*psychological privacy*), as well as control over personal information (*informational privacy*) (Burgoon 1982). With the advent of digital technologies and data collection in almost every area of life, informational privacy becomes an integral part of the other dimension of privacy (Koops et al. 2017). Technologies for Aging in Place collect, store and transmit very intimate data about the social, physical, and psychological self from areas of life which formerly used to be 'offline'. Correspondingly, people feel that they lose control over their privacy and privacy concerns arise.

Privacy concerns have been extensively studied in Information Systems (IS) research (Smith et al. 2011). Privacy concerns in IS regard the collection, unauthorized secondary use and abuse, improper access, and errors in personal information as well as specific concerns over e.g., profiling and de-anonymization, targeted advertisement, identity theft, and credit card fraud (Schomakers et al. 2018; Smith et al. 1996). Solove (2006) categorizes privacy violations from a legal perspective into violations of information collection, information processing, information dissemination, and invasion.

In the context of technologies for Aging in Place which affect health, aging, and home, additional concerns are prevalent: e.g., feelings of permanent surveillance, invasions of personal space, obtrusiveness of the technology, and stigmatization (Boise et al. 2013; Kirchbuchner et al. 2015; van Heek et al. 2017). As medical information, information about mental illnesses is perceived as particularly sensitive (Valdez and Ziefle 2018), privacy concerns are again intensified. Moreover, older adults seem to be generally more concerned about privacy (e.g., Van den Broeck et al. 2015).

Privacy concerns and the acceptance of technologies for Aging in Place are also influenced by technology characteristics, e.g., the what, where, how, and to whom of data collection and transmission as well as the obtrusiveness of the design (Hensel et al. 2006; Rashid et al. 2007). Here, further research is needed to identify and understand specific privacy concerns and how the characteristics of the technology and application context shape these concerns. With the wide range of available technologies, the additional question arises whether privacy concerns and their impact on technology acceptance vary between technologies for Aging in Place.

3 Questions Addressed and Empirical Approach

The aim of the study is to examine, firstly, the specific nature of privacy concerns by potential users of technologies for Aging in Place and, secondly, the impact of these privacy concerns on the acceptance in comparison between two technology examples. A two-step empirical approach was chosen which is depicted in Fig. 1. In study one, focus group interviews were conducted to collect the opinions of potential users towards technologies for Aging in Place with focus on their privacy perceptions and concerns. The outcomes from the focus group study were taken as empirical base for the development of the subsequent quantitative data collection in study 2. In a subsequent survey, the influence of privacy concerns on technology acceptance is quantified with a larger sample and differences between the two technology examples within the domain of technologies for Aging in Place are examined.

For both studies, a sample was targeted consisting, on the one hand, of a group of adults older than 50 years, with varying background regarding their demographic characteristics, health status, and experience with technologies. These adults belong to the technology generations of *technology spread* and *household revolution* (Sackmann and Winkler 2013). On the other hand, adults

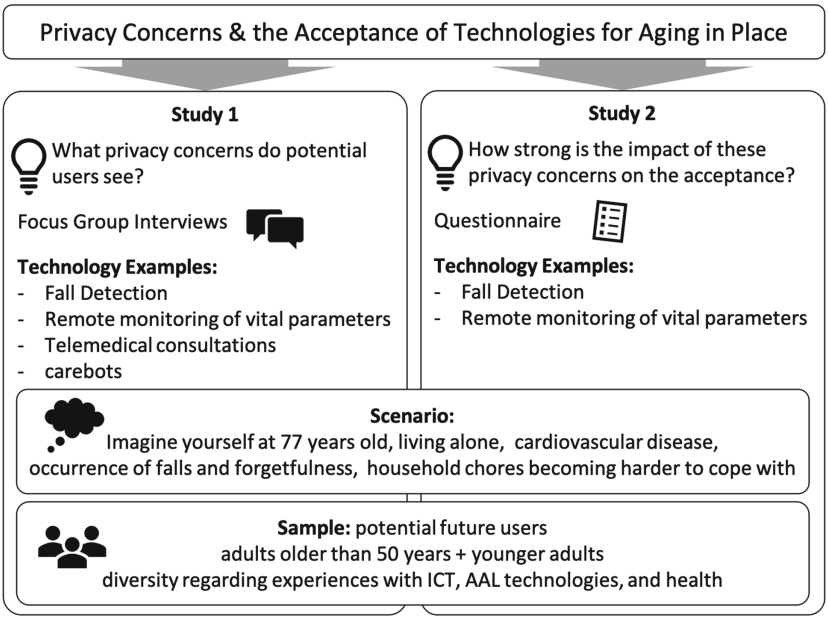

Fig. 1. .

aged 50 years or younger were surveyed to compare opinions and examine age-related effects regarding attitudes towards Aging in Place. These younger adults are from the *computer* or *internet generation* and have been experiencing ICT since their upbringing. All participants were asked to empathize with a scenario of being older and need for support (cf. Fig. 1).

In the following sections, first the methodology and results of the focus group study are reported, before the subsequent questionnaire study is focused.

4 Focus Group Study

In focus group interviews, the interaction between the participants sparks the discussion as they can share, oppose, and argue ideas. Especially when participants are new to the topic and may need some elaboration time to make up their minds, a discussion approach can trigger thoughts that may not come up in in-depth interviews. Thus, a focus group approach was most suited for the first research question regarding the nature of privacy concerns of potential users of technologies for Aging in Place.

4.1 Method

Three focus group sessions were conducted based on a semi-structured guideline. The participants discussed their opinions of technologies for Aging in Place

based on technology examples explained by the moderator. Focus lay on the identification of potential privacy perceptions and concerns. The interviews and focus groups were audio-taped and transcribed verbatim. The study was carried out in German. For the publication, selected quotes were translated to English.

The Procedure: After an introduction to the topic and the focus group, the participants were first asked to brainstorm which technologies they already use in their home to help them at everyday chores and medical tasks. Next, understandings of privacy and examples for privacy within the home environment should be given. With a short explanation of technologies for Aging in Place and the introduction of the first example, the main part of the interview started. The participants were asked to state their general opinion to the technologies and whether they would be willing to use it. They should further elaborate on privacy perceptions as well as conditions that they would pose. After the focus groups, the participants were asked to complete a post-questionnaire, which assessed demographic data, health status, experiences with general ICT and technologies for Aging in Place.

The Technology Examples: The technology examples were chosen to include a wide range of technologies and were introduced with pictures for a better understanding and memorizing. A fall detection system using wearable sensors and one using infrared sensors, remote monitoring (weight, blood pressure, heart rate), telemedical consultations, and carebots were included.

The Sample: Three focus groups interviews were conducted with the aim to cover on one hand, the opinions of adults older than 50 years of both genders with diverse background (e.g., different education levels, health status, and experience with ICT) as well as a group of younger adults. Four women between 53 and 73 years of age participated in the first focus group. The second one included five men aged between 56 and 72 years, and the third one included six students aged between 22 and 30 years (50% women). Overall, the level of education was rather high, with 46.7% holding a university degree, 40% a university entrance diploma, and 13.3% having completed an apprenticeship.

All participants were experienced with general ICT, as they all used a smartphone, tablet, or computer regularly. Regarding their experience with medical equipment, ten participants possessed a blood pressure device, two a blood sugar monitor, and one a hearing aid. No participant had used specific technologies for Aging in Place yet, but five had already heart about such.

Regarding their health status, eight participants were chronically ill, and nine needed to go to a physician regularly. One participant needed to use medical devices regularly and none was in need for care.

4.2 Results

A content analysis was conducted to derive categories from the data with a focus on privacy concerns. These concerns are summarized in the next section.

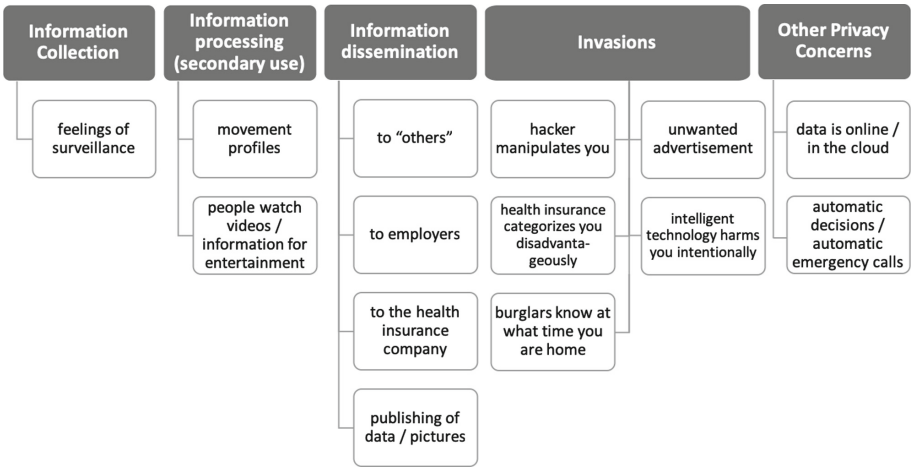

Fig. 2. Privacy concerns of participants regarding technologies for Aging in Place.

Privacy Concerns. The participants expressed various privacy concerns regarding the use of AAL technologies. In Fig. 2, these concerns are categorized into the privacy taxonomy by Solove (2006) which differentiates between privacy violations regarding information collection, information processing, information dissemination, and invasions. Additionally, other concerns were voiced by the participants that could not be allocated to these categories.

The participants expressed that **information collection** itself, e.g., by cameras, microphones, creates feelings of surveillance. Even if a camera would uses additional privacy filters (e.g., Cardinaux et al. 2011), would not send picture material to anyone, or would be switched on only in emergency cases, the mere presence of a camera is felt as a privacy violation.

> *"With cameras, I have to think about George Orwell all the time: 'Big brother is watching you'. It's a disconcerting thought for me."*
> *"I still have a problem with the camera staying in my apartment."*

In the **information processing** stage, unauthorized secondary use of the information is cause for concern. The participants were concerned about movement profiles that could be made based on the data as well as about people who access data, especially videos, for their own entertainment.

"We still have the unknown third person sitting in the same boat. Maybe there are people who get turned on when someone has fallen."

The participants also worried about unwanted **information dissemination** to employers, health insurance companies, as well as undefined others. Moreover, the publishing of information, especially pictures, was discussed.

"Every time that someone gets it [personal data] who I don't want to get it, it's a violation of my privacy."
"Where else does the data go to?' is the important question."
"It is a risk that your health insurance listens, or a pharmaceutical company."
"You fall, break your hip, and two days lay you see yourself in the newspaper."

Various concerns regarded **invasions** of the users life (cf. Fig. 2). The participants especially feared illicit information abuse in forms of hackers, burglars using information to discover at what time the apartment is vacant, or even that the technology itself intends to harm the user.

"But the thought that a hacker might interfere and then somehow manipulates you and harms you."
"We live in a world where there is a lot of mischief. Maybe someone is able to hack the connection. He just takes a look at the camera to see what's going on in the apartment and if it's worth it to break in."
"A terminator that kills you in your sleep or something." "Or it puts your cocktail of tablets together the wrong way."

Moreover, the participants discussed two **other concerns** that did not fit the privacy taxonomy by Solove (2006). They are anxious about personal data being online or 'in the cloud' in general with out naming specific risks or consequences. Also, automatic decisions, like automatic emergency calls, are felt as privacy violation by some participants.

"I think that once you do not have a face-to-face conversation anymore and its mediated by technology than your privacy is at risk."
"As soon as the decision is taken away from me whether I press a button for an emergency or not. I think than it is a violation of my privacy."

An interesting finding is that in some cases the participants evaluate their privacy to be better respected when tasks are handled by technology than when it is done by humans.

"It's a machine, it doesn't judge you. [...] A human would see all the embarrassing things in your apartment and under your bed. Technology doesn't judge you."
"I can decide at what time it is switched on. With a nurse [out-patient treatment], usually a time is allocated to you whether you like it or not."

Imposing of Conditions and the Privacy Calculus. Two additional important themes regarding users' privacy emerged: the participants discussed conditions under which technologies for Aging in Place are acceptable which result from the privacy concerns they perceive. Additionally, they emphasized that privacy concerns need to be weighed against the utility of the technology to make a decision about acceptance as suggested by the theory of the Privacy Calculus.

As **conditions for the acceptance** of technologies for Aging in Place, especially the controlability by the user was empathized. Users shall be able to switch off the technology or single functions at any time, determine what sensors are used, what data is collected, where sensors are installed, and who has access to the data. Also, the granularity with which data is transmitted, e.g, the frequency of data transmission and resolution of the data, and whether the technology may make automatic transmission of data and place automatic emergency calls are important conditions that users want to control individually.

"I think it depends on who is in control and how much control you yourself have over the technology. [...] Can I restrict what it can do? If for example I don't want it to capture my mood, can I tell it not to do that?"
"I think a camera system would be okay, for example if someone from my family saw the picture. If my daughter saw this transmission, it would be okay."
"If he [her grandfather] sends data himself maybe, he is retired and has the time. But if it is sent automatically all the time, I think that would be too much loss of privacy."
"If it only switches on when I have fallen."
"If it would be calculated at home in my system, and then only the information gets out of my network that someone has fallen. Then for me that's okay."

Several participants indicated that they perform **trade-off decisions between privacy and utility**. The perceived risks for the user's privacy is weighed against the possible utility and benefit. This 'Privacy Calculus' is not only performed to form a general opinion on acceptance of the technology, but also to decide the detailed privacy settings, e.g., where sensors may be installed or who has access to data.

"I think that this weighing is important. Are there more benefits, or more risks? What happens with my personal data? Will there be mischief? Who uses it, the health insurance mafia? What is more relevant? I think that most people see more dangers than benefits. Because you just do not fall that often."
"Most people have no interest in my data anyway and if it's analyzed anonymously or in some other way, then you have more benefits than the abstract dangers."
"It makes a differences whether only the neighbor comes by and has a look if everything is in order, or whether the ambulance comes directly. But on the other hand, you would lose important seconds, for example, for a heart attack."

"Especially in those rooms where it would make sense I wouldn't want to have it: bathroom, bedrooms."

5 Questionnaire Study

In the focus group interviews, focus was laid on privacy concerns and perceptions. This resulted in an emphasis of privacy concerns as influence on the acceptance of technologies for Aging in Place. In the subsequent quantitative study, this influence of privacy concerns on the acceptance shall be validated and quantified with a larger sample, thereby comparing two technology examples. Therefore, the acceptance and attitudes towards the two exemplary technologies – a fall detection system and remote monitoring of vital parameters – were assessed.

5.1 Hypotheses

Based on the qualitative results and previous empirical research, the following hypotheses are formulated for both exemplary AAL technologies:

H1. With older *age* the *use intention* decreases.
H2. *Perception of benefits* increase *use intention.*
H3. *Privacy concerns* decrease *use intention.*
H4. *Perception of other barriers* decrease *use intention*
H5. *Privacy concerns* moderate the relationship between *perception of benefits* and *use intention.*

Hypothesis H5 is based on the findings of trade-offs between utility and privacy. This trade-off as it is described by the participant would lead to a stronger relationship between perception of benefits and use intention when privacy concerns are low. In the case that privacy concerns are high enough to outweigh the benefits, the relationship between benefits and use intention would be weaker.

5.2 The Questionnaire

The items of the questionnaire were developed based on the literature study and supplemented with findings from the focus group interviews. The evaluation of two exemplary AAL technologies was assessed in a repeated measures design, a fall detection system (FD) and vital parameter monitoring (VPM). Both technologies were motivated within a scenario, which included the occurrence of falls and the need for daily measurement and diary keeping of vital parameters, respectively.

The questionnaire was structured as follows: First, demographic data (age, gender, education level), health status, experiences with ICT (e.g., smartphone, computers, tablets) and technical self-efficacy (Beier 1999) was assessed. Then, the two technologies were introduced and subsequently evaluated. The order of the technology evaluation was randomized to prevent sequence effects.

The participants evaluated benefits, barriers (including privacy concerns), and use intention for the presented technology. The items were measured on 6-point Likert scales from 0 (*'I do not agree at all'*) to 5 (*'I fully agree'*). Cronbach's Alpha was calculated to confirm the reliability of the scales. In Table 1, exemplary items and the reliability are depicted.

Completing the questionnaire took approximately 20 min. The participants were incentivized with a small donation to a charity organization made for each completed questionnaire. After finishing the questionnaire, the participants could chose to which charity organization the donation should be made.

Table 1. Variables with item examples and Cronbach's α for the fall detection system (FD) and the vital parameter monitoring (VPM), n = 97.

	FD: α	VPM: α
Technical Self-Efficacy, 4 items (Beier, 1999) *I can solve most technical problems on my own.*	.827	
Perception of Benefits, 12 items *I would use the technology, because I would feel safer* *... because I would be able to live independently at home.*	.961	.965
Privacy Concerns, 7 items *I would **not** use the technology, because I would feel monitored.* *... because I worry about abuse of my personal data.*	.923	.913
Perception of Other Barriers, 9 items *I would **not** use the technology, because I worry about its reliability.* *...because I am concerned that the interaction with the system is difficult.*	.874	.877
Use Intention, 4 items *I would like to use the technology.*	.892	.863

5.3 The Sample

The questionnaire was distributed online as well as in paper-and-pencil form. The participants were recruited from the social network of the author as well as online discussion forums. The sample covered a majority of adults older than 50 years as well as younger participants with diverse demographic characteristics, health status, and experiences with technology. 97 participants completed the questionnaire aged between 19 and 85 years ($M = 43.58, SD = 20.58$) including 56.8% older than 50 years and 59% women. The education level of the sample was, on average, quite high, with 55.7% holding a university degree, 7.2% having completed an apprenticeship, and 25.8% holding a university entrance diploma.

Usage of ICT: All participants used either a smartphone, tablet, or computer at least weekly and were, thus, experienced with ICT. The sample reported on average to have a moderately high technical self-efficacy ($M = 3.14, SD = 0.58$, measured from min = 0 to max = 5).

Health Status: 32% of the participants reported to be chronically ill, 32% needed to visit a physician regularly, and 27% needed to use medical technology aids regularly. No participant was in need for professional care.

5.4 Results

Two equivalent regression analyses were calculated to determine the impact of privacy concerns and other influencing factors on the acceptance of the two exemplary technologies for Aging in Place. As assumptions of linearity were partly violated, bootstrapping was used for robust regression. All variables were zero-centered before the regression analysis. Additionally, analyses of variance (ANOVAS) were used to examine differences between the two technology examples. For all analyses, the level of significant was set to 5%.

Vital Parameter Monitoring: The regression model of the prediction of *intention to use vital parameter monitoring* is summarized in Table 2. The model can explain 77.3% of variance in use intention ($R^2_{adj} = .773$). Perception of Benefits shows a large impact on use intention ($\beta = .865, p < .001$). Correspondingly, whether one sees utility in the technology predicts the willingness to use it. Additionally, with increasing age the intention to use vital parameter decreases significantly ($\beta = -.12, p = .029$), thus older adults - the target group of Aging in Place Technologies - are less willing to use vital parameter monitoring in comparison to younger adults. Other variables cannot significantly predict use intention nor is there a moderation effect of privacy concerns on the relationship between perception of benefits and use intention.

Table 2. Linear regression model. Predictors of intention to use vital parameter monitoring, with 95% bias corrected and accelerated confidence intervals of the regression coefficient reported in parentheses (based on 1000 bootstrap samples).

	b	SE B	β	p
Constant	0.224 (−0.928, 0.95)	0.506		.659
Age	−0.007 (−0.012, −0.001)	0.003	−.117	.029
Perception of benefits	0.925 (0.472, 1.151)	0.159	.865	<.001
Privacy concerns	0.058 (−0.332, 0.274)	0.157	.056	.714
Perception of other barriers	−0.157 (−0.384, 0.023)	0.093	−.107	.094
Privacy concerns x Perception of benefits	−0.017 (−0.098, 0.102)	0.037	−.066	.651

$R^2_{adj} = .773$

Table 3. Linear regression model. Predictors of intention to use a fall detection system, with 95% bias corrected and accelerated confidence intervals of the regression coefficient reported in parentheses (based on 1000 bootstrap samples).

	b	SE B	β	p
Constant	0.004 (−0.193, 0.25)	0.076		.956
Age	−0.01 (−0.018, −0.003)	0.004	−.172	.008
Perception of benefits	0.671 (0.445, 0.793)	0.07	.634	<.001
Privacy concerns	−0.191 (−0.392, −0.043)	0.078	−.193	.017
Perception of other barriers	−0.224 (−0.441, −0.058)	0.112	−.156	.048
Privacy concerns x Perception of benefits	0.012 (−0.11, 0.181)	0.038	.019	.76

$R^2_{adj} = .665$

Fall Detection. The predictors of the intention to use a fall detection system is depicted in Table 3. Again, the perception of benefits shows a strong influence on use intention ($\beta = 0.634, p < .001$). Privacy concerns show a significant negative impact ($\beta = -.193, p = .017$) as does the perception of other barriers ($\beta = -.156, p < .048$). As in the case of vital parameter monitoring, age has a weak impact on use intention of fall detection ($\beta = -0.172, p < .008$). There is no significant interaction effect of privacy concerns and perception of benefits. The included variables can explain 66.5% of variance in the intention to use a fall detection system ($R^2 = .665$).

Differences Between Remote Monitoring and Fall Detection. Now, the results of the regression analyses are compared. Privacy concerns and the perception of other barriers only show a significant impact on the acceptance in the case of fall detection, but not in the case of vital parameter monitoring. This goes in line with the differences in agreement to privacy concerns, use intention, perception of benefits, and perception of other barriers (depicted in Fig. 3). Privacy concerns regarding fall detection seem to be more pronounced than regarding vital parameter monitoring, especially in the younger group of adults. But these differences between technologies and the interaction of technology and age are not statistically significant ($F(1, 96) = 3.26, p = .073$ and $F(1, 96) = 1.36, p = .247$). Also, no difference between the age groups can be detected ($F(1, 96) = 0.43, p = .514$).

But, privacy concerns are not rejected in contrast to the perception of other barriers for both technologies. Benefits, on the other hand, are agreed to for both technologies as is the intention to use the technology. For three variables, differences between the age groups seem present, with older adults perceiving more barriers and agreeing less to benefits and use intention than do younger adults. These effects are not statistically significant, with one exception: younger adults show a significantly higher use intention for both technologies than older adults ($F(1, 96) = 6.92, p = .010$).

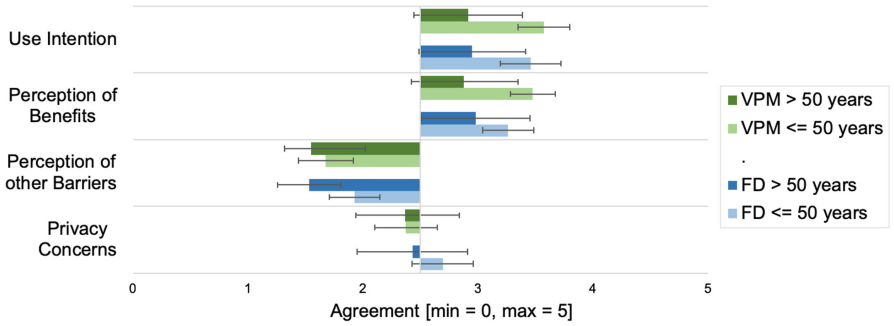

Fig. 3. Differences of the agreement to use intention, perception of benefits, perception of other barriers, and privacy concerns between the fall detection (FD) and vital parameter monitoring (VPM) dependent on age group with 95% confidence intervals (n = 97).

6 Discussion and Conclusion

To unfold their full potential, technologies for Aging in Place need to be accepted by the potential users. But privacy concerns represent a decisive barriers to technology acceptance (Yusif et al. 2016). In order to contribute to the understanding of reasons for privacy concerns, we conducted two studies. In a focus group study, these privacy concerns were identified and conditions for acceptance summarized. Using a questionnaire approach, the influence of privacy concerns on the acceptance was quantified and compared between two typical technologies for Aging in Place - a fall detection system and a vital parameter remote monitoring.

Privacy concerns regard illicit privacy invasions (particularly hackers) and the dissemination of information to unwanted others (e.g., the health insurance company). The major source for concerns is that data is *online* as devices are connected to the internet. Another stream of privacy concerns especially regard feelings and the feeling of loss of control. A camera that does not send any video information to others or automatic emergency calls are also perceived as privacy intrusions, because of a feeling of surveillance and loss of control. Here we see, that privacy concerns in technologies for Aging in Place do not only concern information privacy and data security, but all dimensions of privacy are touched as intimate and private aspects of life are digitized and the physical, psychological, and social self is made more available to others than desired. Therefore, encountering privacy concerns in the context of technologies for Aging in Place only with data security does not fully cover the worries.

Control is the key condition for privacy preservation. Users want to decide what, how, at what time, where, and to whom data is collected and transmitted. Acceptance is formed based on a trade-off decision between privacy concerns and utility - the privacy calculus. Correspondingly, users only accept those technology and functions whose perceived usefulness surpasses the perceived privacy risks. For the development of technologies for Aging in Place, it is thus very important

to provide a clear benefit for the individual and to give users choice and control over the specific system characteristics: which sensors are installed where, at what time is data collected, what data is collected, in what granularity is the data transmitted and to whom? Modular systems – in which users can start with just a few functions that they perceive as useful but can switch on additional functions when the health status declines – are a good solution to consider the privacy utility trade-off as well as changing needs. At the same time, we see that perceptions of privacy risk and benefits vary strongly between individuals. Such modular system would prove a good starting point to account for user diversity as well.

The regression analysis of the questionnaire data shows that the perception of benefits is the best predictor of use intention for both technologies. Privacy concerns, on the other hand, influence use intention only significantly regarding fall detection. Here, privacy concerns are also slightly more pronounced. These results indicate that differences between technologies for Aging in Place need to be considered. Privacy concerns are not similarly high for all technologies and utilized sensor types.

As the focus group discussions focused on privacy, strong privacy concerns were expressed. In the questionnaire, privacy concerns are seen rather ambivalent, not agreed to and not rejected on average. With the triangulation approach using both methods, the advantages and strengths of both methods could be combined, showing which privacy concerns are prevalent plus their influence on use intention and quantification.

Moreover, age and generation effects could be examined in the quantitative approach. Significantly, it is exactly the group which is the main target, the older adults, which shows the most cautious and self-determined attitude towards being monitored. It is therefore of utmost importance to find solutions which do meet both, the wish to stay independently at home on the one hand and the fragile attitudes towards privacy concerns on the other hand. One hypothesis is that the familiarity and identification of ICT is lower in the group of older adults. Today's older adults have not grown up with ICT in their early years resulting in different experiences, expectations, and attitudes towards technology. Age constitutes a carrier variable that is confounded with other variables, e.g., technology generation, experiences, health status. If this hypothesis is true then future older adults will be more positive towards home care data collection. On the other hand it is equally possible that older adults – independently of their generation – might be more sensitive towards any "being cared" heteronomy, even by impersonal technology. Here, longitudinal studies, repeating measurement years later, should be conducted to shed light onto the effects that technology generations have independent from age. The results are needed to plan ahead for the generations of older adults yet to come.

This study could contribute to an understanding of the nature of privacy concerns regarding technologies for Aging in Place and its impact on acceptance. But some methodological limitations need to be considered.

First of all, both methods comprised of scenario approaches and *reported* attitudes. Most participants needed to empathize with a situation that they have not yet experienced. Also, opinions were based on brief explanations of the technologies, not on detailed information or hands-on experiences. The quantitative results are based on a rather small sample of more than averagely educated participants. Future studies should include more participants, particularly more participants with experiences with technologies for Aging in Place and more participants who are not as experienced with general ICT. Also, privacy perceptions are highly culturally influenced (Krasnova and Veltri 2010). With contrasting privacy perception of different cultures, a better understanding of privacy may be reached.

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