The Influence of Privacy on the Acceptance of Technologies for Assisted Living

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Abstract. With population aging and the expected shortage of formal and informal caregivers, emerging technologies for assistive living are on the rise. Focusing on the perspective of the prospective users of these technologies, this study investigates the perceived drivers and barriers that influence AAL adoption. An online survey among 1296 Dutch older adults was conducted. Although loss of privacy was identified as major barrier towards AAL adoption in previous research, the current study provides statistical evidence that these concerns are secondary to the expected benefits of safe and independent living. These findings suggests that older adults consider aging safely in their trusted home environment as a valid trade-off for some loss of privacy. Despite these results, we urge developers to be mindful of privacy aspects when developing AAL applications, as privacy concerns still had a significant negative influence on the attitude towards using AAL.

Keywords: Assisted living · Privacy · Older adults · Technology adoption · Theory of planned behavior (TPB)

1 Introduction

Ensuring good health and wellbeing at all ages is one of the 17 sustainable development goals that were adopted by UN Member states in 2015 [1]. In line with this goal, the European Union has adopted an 'active aging' policy strategy [2]. Emerging assistive technologies, such as smart home technology, mobile and wearable technology, and assistive robotics, are regarded as essential tools to support independent living and healthy aging up to an old age. These technologies are also described as Ambient Assisted Living (AAL) technologies. AAL technologies aim to create supportive environments that help older adult to stay active, monitor their health, preserve their capacities, feel safe, and stay connected with the community. However, their pervasive nature and ubiquitous presence in older adults' personal environments, have serious implications for the older adults' privacy [3].

Indeed, previous studies have consistently shown that concerns about privacy are a major barrier towards AAL adoption [4–7]. Older adults felt uneasy about being permanently monitored and worried about the misuse of their personal information. Third

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parties, including family members, might use monitoring data to patronize them and interfere with their personal life. Older adults were also worried that AAL technologies would intrude upon their personal space and interfere with their normal routine [8–10]. On the other hand, some studies have argued that older adults willingly accept some loss of their privacy in exchange for the expected benefits of AAL, such as independent living and an increased sense of safety [11–13].

The current study seeks to provide more insight into this matter by investigating the factors that determine the adoption of AAL technologies among Dutch older adults. More specific, we investigate the importance of potential adoption barriers, such as loss of privacy, compared to potential drivers of AAL adoption. The discussed results are part of a larger AAL adoption survey which was conducted in the Netherlands. For the purpose of this paper, we specifically focus on the insights regarding the attitude towards AAL technology and the underlying behavioral beliefs, with a specific focus on privacy beliefs.

2 Theoretical Background

2.1 User Acceptance

User acceptance is an important pre-condition for the successful implementation of AAL technologies. Several systematic reviews point to user acceptance as one of the big hurdles for the deployment of AAL technologies in real-life settings [5, 7, 14]. Without a profound understanding of user acceptance, there will be a gap between expert opinions and actual user needs [15]. Consequently, AAL designs are likely to be informed by ageist stereotypes and oversimplified or inadequate user profiles [16–18].

The adoption of a new technology is a complex phenomenon and personal, social, contextual and technological influencing factors need to be considered. Drawing on previous literature, we understand technology adoption as a process over time that consists of several stages from the initial awareness of a new technology to the continuous use [19–22]. The current study focusses on early user acceptance, i.e. the factors that influence the initial attitude towards using AAL technologies.

2.2 Privacy

Privacy is one of the top-of-mind concerns when it comes to AAL technologies. While developers discuss privacy predominately in terms of secure data analyses, transfer and storage, the user's perception of privacy goes beyond adequate data management. Leino-Kilpi et al. [26] distinguish four dimensions of privacy: (1) physical, referring to personal space and territoriality; (2) psychological, referring to the need for self-identity and autonomy; (3) social, referring to control over social interactions, and (4) informational, referring to data protection and data integrity. Looking at the nature and objectives of AAL, these solutions influence user's perception of privacy on all four dimensions.

Physical Privacy. Physical privacy refers to the perception of personal space and territoriality. Many AAL applications are designed to operate in the home environment.

The home is traditionally associated with a feeling of happiness and a sense of comfort, familiarity and belonging. It is regarded as a place of self-expression, self-identity and personal control [23]. The ubiquitousness and pervasiveness of AAL technologies can be perceived as invasive to this personal space, thereby threating one's perception of comfort, security and control. Sensors are often placed in sensitive locations such as bedroom, bathroom or toilet. Wearable AAL technologies permeate the user's personal space as they are directly connected to the user's body. This poses additional challenges in terms of physical interaction, intrusion, comfort and aesthetics [24, 25].

Psychological Privacy. Psychological privacy is described as being in control of cognitive and affective processes related to forming personal values. This dimension is also described as the need for personal autonomy and self-identity [26]. Using assistive devices often evokes negative associations of frailty and dependency and can threaten older adults' self-identity as an autonomous person [8, 27]. Previous work showed that older adults are also concerned that family members might utilize monitoring data to interfere with their personal life, habits and decision making [9, 11, 28].

Social Privacy. Social privacy refers to one's control over social interactions in terms of participants, frequency, length and content [26]. As social isolation is a growing concern for older adults, several AAL technologies aim to stimulate and encourage social interactions. This might also include monitoring social interactions and notifying caregivers in case of lacking social activities. Previous research showed that older adults might be skeptical towards these features as they perceive engaging in social interaction to be a personal choice [11].

Informational Privacy. Informational privacy refers the control and confidentiality of personal information and is a frequently discussed topic in the AAL context. AAL technologies collect, store and transmit an abundance of sensitive personal and health-related information, including vital measurement, medication adherence, sleeping patters and toileting behavior. This information is often shared with family members and healthcare professionals. The combination of various interconnected sensors and devices further challenges the implementation of secure data analysis and storage [14]. Indeed, previous studies have consistently shown that older adults worry about data security and misuse of their personal information [9, 10, 29]. There are also individual differences in the willingness to share this personal data with family members and healthcare professionals [6, 10].

Prospective Benefits as a Trade-Off for Privacy. Although privacy appears to be an important barrier towards AAL adoption, there are several researchers that argue that older adults will accept this loss of privacy as a trade-off for the associated benefits of AAL [11, 13, 30]. Townsend et al. [13] conclude that the desire for autonomy and aging in one's own home environment is valued higher than privacy. A similar conclusion was drawn by Wild et al. [12] who found that participants' privacy concerns were secondary to expectations about advanced safety, health and independence. However, these findings are not routed in statistical evidence.

2.3 Modeling the Underlying Beliefs of AAL Adoption

To develop a better theoretical understanding of the underlying beliefs that influence early user acceptance and make statically grounded inferences about their relative importance, we developed a conceptual model of AAL adoption. For the purpose of this paper, we focus on the attitude part of the model together with the underlying behavioral beliefs including loss of privacy.

The theory of planned behavior was used as the theoretical starting point for the AAL adoption model. The theory of planned behavior (TPB) [31] stems from the field of psychology, and offers an integrated and overarching theory of human behavior. TPB has been successfully applied in technology acceptance research [32, 33] and also in the context of assistive devices [34].

Attitude towards behavior is a core construct in the theory of planned behavior, as it is one the immediate ascendants of the intention to perform future behavior [31]. In the context of the current study it is defined as '*the degree to which using AAL technology is positively or negatively valued*'. Attitude towards behavior is determined by several behavioral beliefs that are defined as '*the expected outcomes of using AAL technology*'. We followed Taylor and Todd's approach to decompose the underlying belief structure into multi-dimensional belief constructs. This approach provides a better and more detailed understanding of the underlying belief antecedents and therefore, a better guidance for design and implementation efforts of AAL [35]. The relevant behavioral beliefs for AAL adoption were elicited from previous studies in field of AAL adoption [e.g., 5, 11, 12] and in-depth insights from our own qualitative studies [9, 28]. Besides loss of privacy, loss of human touch (i.e., the fear of technology substituting human care) was hypothesized as a negative belief antecedent of attitude. Safe and independent living and relief of family burden are proposed to be positive belief antecedents (see Fig. 1).

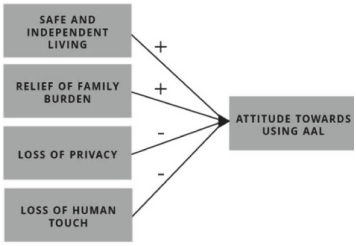

Fig. 1. Extract from the conceptual model of AAL adoption: attitude and the underlying behavioral beliefs

3 Method

3.1 Sample

To test the conceptual model of AAL adoption, we conducted an online survey among Dutch older adults between 55–85 years. The online survey was administered by a

Dutch ISO-certified research agency specialized in online fieldwork. Their panel consists of 110.000 members with diverse demographic background to ensure representativeness of the Dutch population. Participants were invited via e-mail to participate in exchange for credits. For the sampling, we used pre-defined age quota to achieve a sample that was representative for the Dutch older adult population [36]. After screening the data of some cases were removed due to straight lining, exceptionally short response times, incomplete response pattern or insufficient understanding of the AAL concept.

The final sample consisted of $n = 1296$ participants of which 49% were male and 51% were female. The age distribution was aligned with the Dutch population with 43% in the 55–64 years age group, 38% in the 65–74 age group, and 19% in the 75–85 age group. Overall subjective health and quality of life were measured with a single item on a 5-point scale ranging from 1 = poor to 5 = excellent. Subjective health averaged around the midpoint ($M = 2.95$, $SD = .97$) while quality of life had a slight tendency towards the positive end of the scale ($M = 3.21$, $SD = .91$). The majority of the sample (95%) had no direct user experience with AAL applications.

3.2 Survey Materials

Prior to completing the survey, participants viewed a short video animation explaining the concept of AAL (https://youtu.be/TZfy5KW9kOY). The video animation evolved around the persona Ben, an older adult, and his daughter Sophie. The scenario contained several examples of AAL technologie including smart home technology for activity monitoring and fall detection; a reminder system for medication and appointments, and an assistive social robot. Following the video, participants were presented with visuals from actual AAL products that are ready-to-market or already available on the Dutch market: the Sensara activity monitoring system [37]; theDayclocks reminder system [38]; and care robot Zora [39]. The visuals were accompanied by a short description of the key features of each product. To check the participants understanding of the animated video and the visuals, a control question was included after both stimuli. Participants who indicated insufficient understanding were excluded from further analyses. After viewing the video and photos, participants were directed to the AAL adoption survey.

3.3 Measurements and Data Analyses

Measurements were partially based on existing scales, and partially new scales were developed using the topics from AAL literature and our own qualitative pilot work.

A 5-point Likert scale was used as a response scale, ranging from 1 = strongly disagree to 5 = strongly agree. Due to the novelty of the concept of AAL we also included a ‘don’t know’ option. A 5-point semantic differential scale was used as a response scale for the attitude items. Several pre-tests were conducted to improve the psychometric properties of the scales including cognitive interviews with 3 older adults. Finally, a pilot study with $n = 320$ older adults was used as a calibration sample to test the initial measurement model and refine the final survey instrument. The final attitude scale consisted of 6 items ($\alpha = .93$). Safe and independent living was measured

with 7 items (α = .88). Relief of family burden was measured with 4 items (α = .85). The loss of privacy scale consisted of 6 items (α = .93) and loss of human touch was measured with 4 items (α = .87) (see Table 1).

Table 1. Measurements

Variable name	No of items	Example item
Attitude towards using AAL	6	I (like/dislike) the idea of using AAL technology
Safe and independent living	7	If I use AAL technology, I will feel safer in my home
Relief of family burden	4	My use of AAL technology will give my family members peace of mind
Loss of privacy	6	Using AAL technology will feel like an invasion into my personal space
Loss of human touch	4	If I use AAL technology, I will get less personal attention

4 Results

4.1 AAL Adoption Model

Before we focus the attitude part of the model, the fit of the greater AAL adoption model is discussed.

Structural equation modelling (SEM) was used to test the proposed adoption model. Prior to testing the structural model the measurement model was specified using maximum likelihood estimation (ML) with FIML for the missing data because the data were approximately normally distributed. All indicators showed good standardized factor loadings (>.50) and loaded significantly on the respective latent variable ($p < .001$). Some indicators were iteratively removed due to low squared multiple correlation values (<.40). The final measurement model showed adequate model fit (normed chi-square (2.98), RMSEA (.039), SRMR (.05), CFI (.93), and TLI (.92)). In a second step the structural model was tested. The proposed model showed adequate model fit for the observed data (normed chi-square (3.06), RMSEA (.040), SRMR (.06), CFI (.93) and TLI (.92)) and explained 69% of the variance in intention to use.

4.2 Descriptives

The overall attitude towards using AAL technologies was positive among Dutch older adults ($M = 3.73$, $SD = .78$). Looking at the underlying behavioral beliefs, participants had strong beliefs that AAL technologies could benefit their safety and independence ($M = 3.92$, $SD = .52$). Participant also expected that AAL could relieve the physical and emotional burden of their family members ($M = 3.67$, $SD = .65$). Negative beliefs regarding loss of privacy ($M = 3.14$, $SD = .87$) and loss of human touch ($M = 3.13$, $SD = .83$) were somewhat less prevalent and scored just above the midpoint of the scale (see Fig. 2).

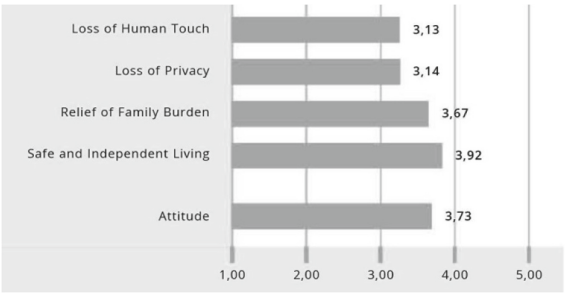

Fig. 2. Mean composite scores of the overall attitude towards using AAL and the behavioral belief constructs

4.3 The Relative Importance of the Behavioral Beliefs

All hypothesized paths between attitude towards using AAL and the underlying behavioral beliefs showed significant standardized path coefficients at a $p < .001$ level. Together these variables explained 71% of the variance in attitude ($R^2 = .71$) (see Fig. 3).

Loss of privacy had a negative influence on the attitude towards using AAL technology ($\beta = -.19$), but was less important than concerns about the loss of human touch ($\beta = -.25$) touch and expectations about safe and independent living. Safe and independent living had a positive influence on attitude towards using AAL technology and was found to be the most important influencer ($\beta = .51$). Finally, relief of family burden had some positive influence on attitude ($\beta = .12$), but was the least important influencer.

This means that older adults' initial attitude towards using AAL technology is mainly driven by the expectation to feel safer and to be able to age independently, and somewhat less by concerns about privacy and the loss of human touch.

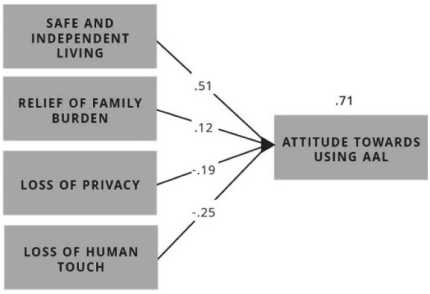

Fig. 3. Extract from the validated model of AAL adoption: attitude and the underlying behavioral beliefs

5 Conclusion and Discussion

This study investigated the relative importance of potential adoption barriers compared to potential drivers of AAL adoption. Hereby, we were especially interested in the role of privacy in informing the initial attitude towards using AAL technologies. In our conceptual model of AAL adoption, loss of privacy and loss of human touch were proposed to have a negative influence on attitude. Safe and independent living and relief of family burden were hypothesized to have a positive influence on attitude. The hypothesized relationships are an extract of a greater AAL adoption model which was validated through an online survey with a representative sample of Dutch older adults (n = 1296).

In accordance with our expectations, attitude was affected by older adults' beliefs about loss of privacy, loss of human touch, safe and independent living and relief of family burden. While privacy concerns had a significant influence on the initial attitude towards using AAL technology, these concerns were less important than previous AAL literature implied [4–7]. Our results showed that older adults' initial attitude is mainly driven by expectations about independent aging and increased safety and somewhat less by concerns about privacy and the loss of human touch. Hence, we found statistical evidence for the claim of Townsend et al. [13], who suggest that older adults are willing to accept some loss of privacy as a trade-off for aging independently at home. Townsend et al. [13] argue that the loss of autonomy associated with nursing homes is perceived as more severe than the loss of privacy associated with sensor technology. Wild et al. [12] also found that older adults' privacy concerns were secondary to the perceived benefits of AAL in terms of health, safety and independence. Still, given the prevalence of the privacy discussions in AAL literature, it is still somewhat surprising that privacy was not a stronger driver of attitude among our participants.

An explanation for these findings could be attributed to participants' limited user experience with AAL technologies. The majority of the sample (95%) had never used an AAL application. Hence, answers were based on the material provided in the survey or previous knowledge participants had about AAL technologies. Privacy beliefs might become more prevalent once the technology is in use and users have gained some user experience. Lorenzen Huber et al. [40] and Boise et al. [10] found that privacy concerns can increase over time after active exposure and interaction with the technology. Future research should therefore investigate the trade-off between privacy concerns and expectations about increased safety and independence among participants which have used AAL over a longer period of time. Other researchers attribute lower informational privacy concerns to a limited technical knowledge and consequential lower awareness of security risks [11, 41].

With this in mind, and given the fact that privacy concerns still had a significant negative influence on attitude towards using AAL, we still urge developers to be sensitive to the user's physical, psychological, social and informational privacy and keep privacy protection as a focal point in the development process. Advanced data protection techniques and security protocols have to be implemented to protect the user's personal information. Hardware has to blend seamlessly with the surroundings to minimize interference with the user's sense of home. Older adults should control the

decision making regarding sensor types, location and data recipients. Reciprocal [40] or self-monitoring [42] approaches can counter feelings of inferiority and paternalism and stimulate agency.

The results of this study should be considered in the light of some limitations. First, the current study focused on early user acceptance. Consequently, the majority of participants had never used AAL technologies, and opinions were restricted to the participants' expectations towards these applications. While insights on early user acceptance are still very valuable for the design and development of AAL [13, 43], we have already noted that privacy perceptions might change over time. Future research should therefore deploy longitudinal designs that investigate later stages of acceptance. Second, our sample was bias towards older adults with internet connection and basic technology skills as data were collected via an online survey instrument. However, according to Statistics Netherlands [44], most Dutch older adults are active internet users. Hence, we still consider our sample as largely representative for the Dutch older adult population. Third, previous research suggested that privacy concerns are influenced by cultural values [45]. Hence, future research should validate the current findings in a different cultural context.

Awaiting future research to address these issues, the current study provides statistically grounded insights about the acceptability of AAL technologies and specifically the meaning and influence of privacy in forming an initial attitude towards AAL use. Our work therefore contributes to a more user-driven discourse in AAL research and development.

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