Perceptions of Personal Privacy in Smart Home Technologies: Do User Assessments Vary Depending on the Research Method?

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Abstract. Nowadays all Western societies are confronted with the challenges resulting from demographic change, which are (partially) manageable by technical innovations, ranging from sophisticated single devices up to Ambient Assisted Living. However, exceeding the threshold to people's homes evokes diverse privacy concerns. In this paper, aspects of personal privacy are exposed and validated by three different research methods: focus groups, questionnaire, and an experimental study.

The results of the perceived relevance of privacy across the three methodologies showed a decrease of the attributed importance from the focus group to the hands-on experimental study and an increase of the variability of the data. In order to gain genuine exhaustive information about the user's perceptions of (aspects of) new technologies it is therefore insufficient to rely on one single research method. Instead, a multi-method research approach is postulated.

Keywords: Privacy · Ambient assisted living · Ehealth · Multi-method research · Focus groups · Questionnaire · Living-Lab study

1 Introduction

The rapid development in information and communication technology (ICT) and its growing application possibilities in the everyday lives of aging populations have long raised concerns about the individual privacy. Currently, a particular emphasis in this topic is placed onto the use and acceptance of smart home technologies that are meant to support residents especially in their health duties (e.g., measurements of vital parameters, medication, rehabilitation exercises) and in accomplishing their other daily functions. Integration of health-supporting technologies in the domestic area (e.g., health monitoring system) fundamentally changes social and communicative pathways in people's lives, and the users' perceptions of personal privacy in this context may greatly vary from the use of technology in isolated and deliberately determined situations.

The conception of privacy is highly complex and involves different perspectives and dimensions that, depending on social, physical, and cultural factors, considerably vary between individuals. An additional consideration is that the concept of privacy – and the term relates, at this point, to the individual's private sphere and not exclusively to

the privacy in terms of data protection – might be evaluated differently by the users depending on the chosen research method. To examine this phenomenon, in this paper we describe the (potential) users' perceptions of personal privacy in the context of acceptance of medical ambient technology, comparing the results of three different research methods: focus groups, a quantitative survey, and an experimental usability study.

Demographic Change and the Concept of Ambient Assisted Living. It is an obvious fact that most Western societies undergo a demographic change. The decreasing birth rates in the last decades, on the one hand, and the medical improvements, on the other hand, lead to an aging society, recognizable already today and increasing the next 40 years [1, 2]. The present elderly care systems work at their limits regarding human and accommodation resources. The good news is that in addition to all political efforts or the job-related migration [3, 4], there are some technical solutions dealing with the challenge to support the major wishes of the elderly: being healthy and staying in their own four walls as long as possible [5].

Currently, there are several technical applications on the market and under research to support elderly people's staying at home. With the improvement of conventional information and communication technologies and telemedical devices the possibilities to save doctoral consultations for minor checkups are a wide and well researched field of technology [6]. In combination with electronic health devices (eHealth technology), measuring vital parameters connected for telemonitoring even elaborated consultations can be made while staying at home [7]. There are also wearable solutions for emergency calls with buttons on bracelets or necklaces. Currently, the research goes even further, integrating eHealth devices from wearables to implants with an improvement in size, precision, and possibilities [8]. Furthermore, also nursing staff at home – the number of which unfortunately decreases continuously due to the demographic shifts – could one day get support by robot colleagues [9].

Single devices often encompass all of the solutions above. The combination and seamless integration of technology devices into the living spaces, making the home a smart home, leads to the research field of Ambient Assisted Living (AAL) [10]. As we are on the cusp to its commercial realization, current research primarily takes place in living labs [11], where future users can get hands-on experience and the functionality and usability of these technologies can be optimized.

This short introduction from present eHealth systems to Ambient Assisted Living leads to one not yet mentioned, but crucial factor: the user's acceptance. In most of our interdisciplinary research at the Human-Computer Interaction Center the focus lies on the user's point of view. The overall acceptance of health technology, which aims on a quite sensitive area of life, is bound to several key factors. In this work the focus is directed to one currently highly debated topic, dealing with the importance of individual privacy in connection with ambient technologies in home environments [12].

Privacy Concerns as a Key Barrier in Medical Technologies at Home. A specific focus of AAL technologies is naturally directed to the question to what extent such systems respect the fragile trade-off between two different poles: On the one hand, the

wish to live independently at home, to feel safe, secure, and fully cared for, and on the other hand, due to a continuous health monitoring the feelings of loss of control, the concerns about the protection of individual privacy and the refusal to tolerate any intrusions in the private sphere.

The omnipresence of information and communication technologies, especially at home, may be perceived as a violation of personal intimacy limits, raising concerns about privacy and loss of control [12, 13]. Recent studies show that this trade-off is not only extremely difficult for individuals, but it is additionally affected by user diversity like e.g., age [14], gender [15, 16], culture [17, 18], or health status [19]. Also, the trade-off varies for different stakeholders: Patients might have a different perspective than family members, caregivers, or medical personnel [20]. So far, privacy issues in technologies are mostly addressed from a legal and technical point of view (e.g., [21]). Though both perspectives are naturally important for the feasibility and broad implementation of such systems, individual perceptions of privacy are an indispensable prerequisite for a vast acceptance and sustainable solution. From this it follows that the perceptions of individual privacy and intimacy limits must be considered from the beginning in the technology development.

Validity of Reported Concerns in Different Methodological Settings. The implementation of the user's privacy and trust perceptions in the technical design is, however, not easy to realize. One reason is the topic itself: The exploration of the medical technology in the context of home environment and the question how far users would tolerate it, is an extremely sensitive and serious issue associated with feelings of being old, ill, dependent of others, and is thus accompanied by stigma and decline [13, 22].

Another reason is the way how privacy perception is examined, i.e., the respective empirical methodology and the validity of the results. In most of the studies, more or less healthy persons of a wide age range and with different professional backgrounds had been requested to evaluate the acceptance of AAL systems in order to learn, which persons would be willing to adopt such systems in their living spaces under which circumstances. Yet, while such approaches are technically sound, there are still some doubts with respect to the validity of the findings. It has been argued that users who are not actually concerned by (chronic) illness and/or old age and the associated consequences of health decline that require medical monitoring system at home, cannot evaluate the "real" situation and thus over- or even underestimate such a situation [19, 22]. This is due to the fact that no experience with smart home technology is present and that persons tend to overemphasize their sensitiveness towards privacy violations if their judgments only rely on the imagination of using it [23, 24].

2   Methodological Concept: A Multi-method Approach

In this paper, privacy concerns in the context of AAL technologies are explored with two major foci: Firstly, privacy and intimacy concerns were empirically assessed among participants of a wide age range (19–98 years of age), both sexes, and with different health states (healthy young, healthy old, more or less diseased young and ill elderly persons). Secondly, different methodology approaches were used: focus groups discussions, a

questionnaire study, and an experimental study in a living lab environment (Future Care Lab©, RWTH Aachen University, Germany), in which participants are able interact with an ambient technology integrated in a home.

In focus groups, cognitions and argumentation lines of persons can be collected, allowing an early evaluation of emotional and ethical concerns, like hopes, wishes, and requirements of the users, prior to technology development. Quantitative questionnaires, in contrast, enable to quantify the relative extent of attitudes towards the topic across a broader sample of participants, contrasting thereby positive and negative factors, and allow a screening of the degree to which user factors might influence the evaluations. Finally, a living lab experiment allows studying users in a quite realistic environment, thus enabling to understand evaluations in a socially framed context in which users can touch, feel, and interact with the technology at issue. In Fig. 1, the different empirical approaches are systemized.
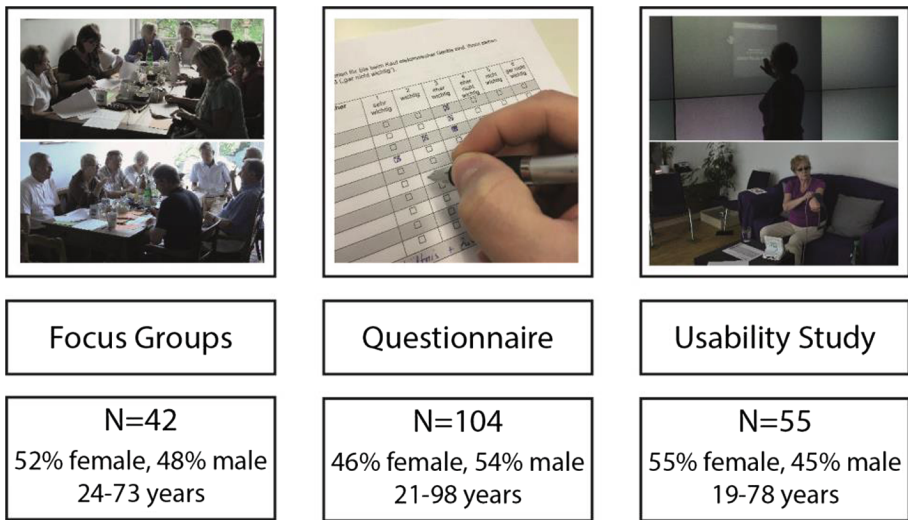

Focus Groups	Questionnaire	Usability Study
N=42	N=104	N=55
52% female, 48% male	46% female, 54% male	55% female, 45% male
24-73 years	21-98 years	19-78 years

Fig. 1. Methodological approaches validating privacy aspects associated with AAL technologies

Focus Groups Study. The focus groups were conducted with N = 42 participants in total, which resulted from five different sessions. According to the topic of the study, the discussion groups were composed of younger and older adults (age range between 24 and 73 years; M = 57.3, SD = 13.7) and assigned to the particular groups considering the users' gender (52 % female). Such composition of the focus groups was meant to support the dynamics of the conversations, allowing better access to the age- and gender-specific perceptions.

The aim was to identify and discuss peoples' ideas of individual privacy when using ambient technology: In the first place, this topic was debated in the context of general use of popular information and communication technology devices (e.g., mobile phone, personal computer), but special emphasis was applied to medical devices and health-related

technology systems integrated in home environments. On the basis of the findings derived from this qualitative study, a questionnaire was developed to validate the data in a quantitative way.

Questionnaire Study. In the survey study quantitative data of N = 104 participants aged between 21 and 98 years (M = 46.3, SD = 17.8; 46 % female) were analyzed. The aim was to quantify how relevant the previously identified aspects of individual privacy (e.g., invisibility to outsiders, intimacy, anonymity) are for the acceptance of medical technology on a more representative population level.

One part of the questionnaire surveyed, firstly, how important for the randomly chosen respondents are such issues as for instance discreetness, intimacy, anonymity while using health-supporting devices, secondly, how they perceive the system security of such technology (e.g., "How important is the highest possible data protection to you?"), and thirdly, how they assess the aspects of safety regarding the health monitoring (e.g., "I would use medical devices, because the storage of my vital data would enable a quick access in case of an emergency"). The classification of relevance of the aforementioned items was made on a six-point Likert-scales ranging from 1 ("not important at all") to 6 points ("very important"). For statistical purposes all the items were summed up to a privacy-subscale, reaching a maximum of 66 points.

This method was applied to gather information from a larger adult population in order to be able to generalize the privacy outcomes – at least the investigated ones – in the context of living in a smart home environment.

Experimental Usability Study. The usability study focused on the acceptance of health-assisting technology in living spaces and considered privacy as one of many factors that may influence the perceptions of its usability. The evaluation of the focused topic was performed by N = 55 test persons who took part in a living lab experiment that examined people's interaction with a complex ambient technology. The age of the test persons ranged from 19 to 78 years (M = 35.9, SD = 14.9) and the proportion of men (45 %) and women (55 %) was well balanced.

After working on two experimental tasks (i.e., verification of personal vital parameters using built-in health-relevant devices like blood pressure meter), and therefore extensive interaction with the technology, participants evaluated in addition to the well-known usability criteria (e.g., complexity of the system, learnability, ease of use) the following personal privacy items:

- "It bothers me that my data might be visible and/or accessible by others."
- "I wish for a personal access code for the system to protect my privacy."

The test persons were requested to indicate the degree of their (dis)agreement on a seven-point Likert-scale (1 = "strongly disagree" to 7 = "strongly agree") and a sum of the two items was formed (max. = 14 points) for further statistical analyses.

In the third study, thus, participants assessed the mentioned privacy requirements using yet another method: In contrast to the first and the second research study – which, envisioning the use, solely allow the anticipating of opinions in this subject matter – the evaluation of privacy here was signified after a direct interaction with the technology in

a natural setting and performed in context of an everyday activity. It is therefore to be expected that such results are very meaningful.

3   Results

The results of the presented studies regarding opinions of the relevance of personal privacy in using ambient assistive technologies were elaborated from scratch according to the user-centered research. The findings of a previous study, thus, were analyzed and consecutively validated by means of another research method as it was described above.

In this paper, the statistical analyses are mostly left at the level of univariate analyses and the outcomes regarding privacy aspects are presented by means of a central tendency of a variable and its dispersion [mean values (M) and the associated standard deviations (SD)]. Moreover, inferential statistic analyses are used to explore differences between age and gender groups; for this purposes t-tests and analysis of variance are used depending on the nature of the analyzed data. The level of statistical significance is set at 5 %.

Results of the Focus Groups Study. In the introductory part, participants were encouraged to talk about all the technical devices they use in their everyday life. Focusing on such common ICT devices, it was then questioned which information and communication modalities (e.g., integrated camera, microphone, monitor, etc.) the participants would allow in their own homes and where (e.g., living room, kitchen, bedroom, bath). In addition, it was queried what **"control"** means in the context of (medical) technology, focusing on people's perceptions regarding (health) monitoring and surveillance.

The discussions in all focus groups uncovered different perceptions and aspects regarding personal privacy. Ambient technologies entering private spaces brought up questions addressing intimacy and the control to switch off any technology whenever required. Questions on health-related safety and data security when monitoring individual parameters resulted in heated debates. Who has control over the data and who is watching the observers? How can anonymity be ensured? How is the critical trade-off between autonomous living at home monitored by ambient technology system vs. living in a retirement home evaluated?

The results of a short questionnaire about the valued importance of privacy that was handed out to each participant showed clear results. With a mean of $M = 9.7$ out of 10 possible points ($SD = 0.8$) the importance of privacy was evaluated as extremely important.

Results of the Questionnaire Study. The validation of the privacy aspects that were found by means of focus groups was realized by the quantitative questionnaire. The outcomes regarding the importance of personal privacy appeared somewhat attenuated in comparison to the assessments in the forerun qualitative method. Overall the mean of $M = 48.6$ out of maximum 66 points ($SD = 11.6$) was reached (see Fig. 2, right). This is a high value that makes evident that the individual privacy is in general evaluated quite high. On the left side of Fig. 2 the means of the single aspects of privacy are detailed: The most privacy requirements reached on average a high importance (means
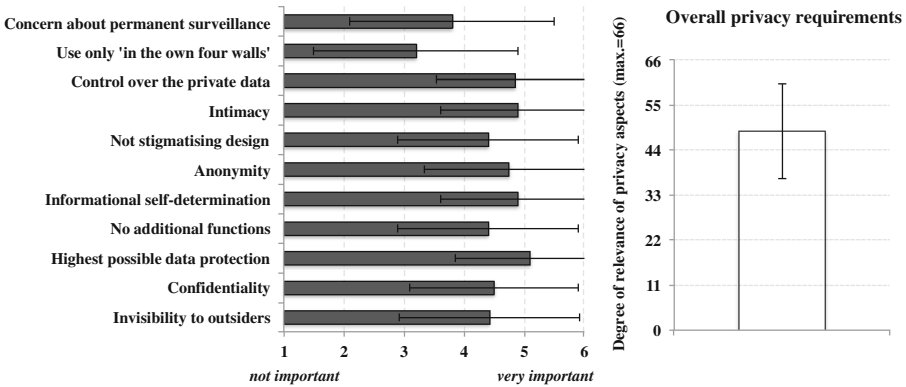
Fig. 2. Assessments of privacy aspects in detail (left) and in general (right) in the questionnaire study (N = 104).

around $M = 5$ out of 6 possible points) – the most pronounced were the highest possible general data protection ($M = 5.1$, $SD = 1.2$), the protection of intimacy ($M = 4.9$, $SD = 1.3$) and the perceived control over the private data ($M = 4.8$, $SD = 1.3$), while no great importance was attributed to the technology use only 'in the own four walls' ($M = 3.2$, $SD = 1.7$).

Additional statistical testing for age [$F(2, 94) = 0.8$, p = n.s.)] and gender effects [$t(93) = -1.4$, p = n.s.)] concerning the presented assessments revealed no significant differences in this regard.

The overall quite high privacy requirements consolidated in a unified privacy-subscale show distinct awareness of this topic in the examined context, but in the end they do not confirm privacy as a main driver for the acceptance of ambient technologies.

Results of the Usability Study. In the experimental study, the importance of the individual privacy topic was examined among other system usability aspects, without putting a strong emphasis on it.

The participants, who in this study assessed the usability of the technology were asked during the experimental setting, firstly, to what extent they feel bothered by the visibility and/or accessibility of their personal health data by third parties. The answers turned out ambiguous reaching in the whole sample a mean of $M = 4.1$ ($SD = 2$) out of 7 points, which in concrete terms means neither unequivocal consent nor unambiguous rejection of this privacy aspect. Secondly, the test persons had to evaluate whether they wish for a protecting code for their personal data. In this case, the analysis revealed rather a rejection than an approval ($M = 2.8$, $SD = 2.1$) of this kind of privacy protection. The mean values of both privacy aspects examined here are presented in Fig. 3 on the left.

Using the experimental research method, the resulting score of privacy not even reached the midpoint of the relevance scale ($M = 6.9$, $SD = 3.6$ out of 14 points), showing overall rather strongly mitigated significance of the individual privacy for the use of health-supporting technology in ambient assisted living.

Furthermore, neither a significant effect of age [$F(2,53) = 3.3$, p = n.s.)] nor gender effect [$t(53) = -0.9$, p = n.s.)] was revealed for the privacy in the usability study.
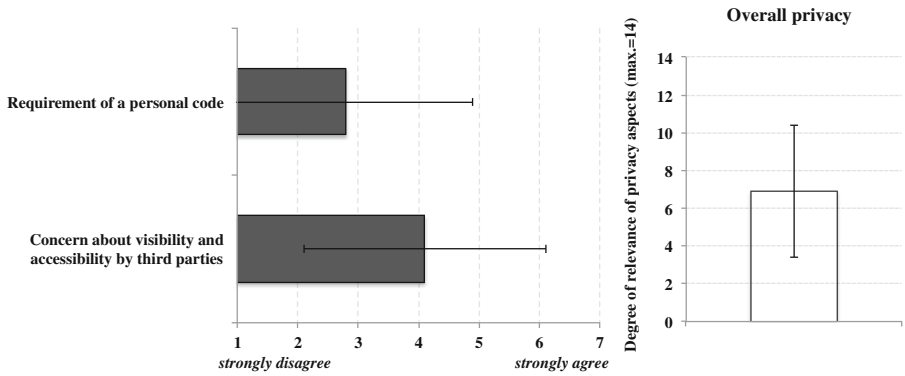
Fig. 3. Assessments of privacy aspects in detail (left) and in general (right) in the experimental usability study (N = 55).

Comparison of the Results of Different Research Methods. In order to "compare" the results for the valued importance of privacy concerns, depending on the respective methodology, a standardization of quantitative outcomes is necessary. Strictly speaking, one could argue that a numerical standardization might not be appropriate in this context, as different persons, scales, and empirical framings had been used across the three methodological approaches. Though, in order to get an impression how far the used method influences and modulates the point at issue, we normalized quantitative results of all approaches and scales to a 10-point scale ranging from −4.5 (= not important) to 4.5 (= very important). The outcomes are depicted in Fig. 4.
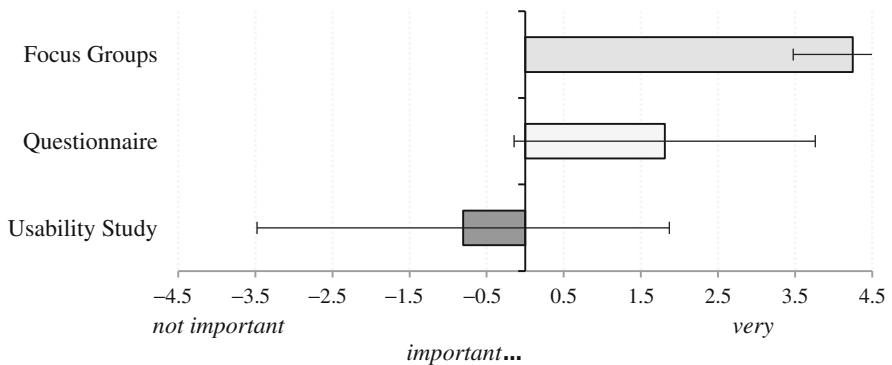

Fig. 4. Comparison of the applied research methods: Mean importance of privacy aspects

As can be seen, it is astounding in how much the relative extent of privacy concerns depends on the research method. The most concerns were collected in focus groups; thus, the individual privacy here was regarded most important, followed by the results from the questionnaire. The lowest degree of concerns was found in the experimental approach in living lab, corroborating that the nature and the extent of concerns naturally decreases with increasing reality of Ambient Assisted Living as a base for the evaluation.

4   Discussion

The presented research clearly corroborates previous scientific findings that the phenomenon of privacy represents a serious concern in the context of a successful integration of AAL technologies in home environments (e.g., [5, 12, 24]). The results of the above studies can be briefly summarized: In all three studies it was showed that people seriously contemplate the aspect of privacy in their considerations of the acceptance and adoption of such an innovative technology. Although the (potential) users acknowledge the huge potential of health-supporting ambient technologies being aware of usefulness and benefits they yield, the concerns about the protection of the private sphere and the fear of losing their intimacy is dominant and deeply anchored. Interestingly, these perceptions of privacy and intimacy prevail independently of age and gender, representing thus an old and profound, even "archetypal" concern.

However, from a methodological point of view the results were astounding, if not alarming. According to the presented findings, the intensity of privacy concerns is dramatically dependent on the respective empirical method with which the focused topics are captured. The more distinct – this means isolated from other contents – the approached topic was within a research method and the more people were allowed to discuss (focus groups) and to envision possible scenarios associated with it (focus groups, questionnaires), the more pronounced were the respondents' concerns about the possible violations of their personal privacy. In contrast, whenever the examined topic was embedded into another matters, or when users were confronted with quite realistic circumstances (in form of living lab experience) and their attention was not only directed to this one topic, the privacy concerns considerably decreased.

Nevertheless, in all three methodological settings participants realized the different benefits of ambient technologies and seemed to appreciate their huge potentials for themselves and their families; this fact is very promising for the societal challenge to meet the demographic change. Yet, it is noteworthy that according to the high standard deviations in the evaluations of the research approaches there are always persons who show substantially higher objections than others, even though the relative amount is completely different. These facts and the disparity of the outcomes, despite a consistently successive, methodologically strongly associated research approaches, clearly show an uncertainty whether the phenomenon under study depends on the method used (phenomena dependence of method), or whether the chosen method is simply inappropriate for the corresponding phenomenon (methods dependence of phenomena).

Given such ambiguity, it is not easy to unequivocally decide, which method leads to the real, genuine, and the most valid results. Let us firstly consider focus groups as a method: On the one hand, it could be argued that the possibility for the participants to deliberately discuss the topic of personal privacy is the Via Regia to uncover the relevant motives. Following this line of reasoning, we must assume that the other used methods, evaluating privacy as an aspect among others (survey, experiment) may entirely underestimate the significance of the examined phenomenon. On the other hand, one could polemize that focus group discussions might artificially exaggerate and overestimate the problems, arguing that the more room for discussions is given to the participants in early

stages of the developmental process, the more there is space for developing an antagonist position that focuses on potential risks and the uncertainty in connection with a novel technology (according to the motto: if you ask for problems, you will receive them). Such an approach would clearly suggest using additional methods that accordingly validate the results of the initial discussions.

On the base of the present findings no clear statements can be made. The steady weakening of the relevance of the privacy aspects with each research method used complicates a distinct indication of a certain direction in this regard. However, especially in the context of medical technology, there are certain reasons to assume that the potential usage barriers and perceived benefits can be only fully understood and assessed if users are able to actively interact with the ambient technology in a home-like environment [19, 24]. Therefore, an experimental space, like it is given in the surrounding of a living lab, is of central importance for the examination of privacy concerns not only out of validity reasons, but also because patients and caregivers need to experience and "feel" the ambient technology in order to evaluate it properly [25]. As opposed to this, persons may overemphasize their sensitiveness towards privacy violations if their judgments rely only on the imagination of using it (questionnaire method) [22–24].

In view of the results it is evident how much the examination of a research object depends on the chosen scientific method. This paper therefore posits that the application of different research methods is mandatory, especially when investigating or exploring (new) influencing factors in the process of launching technology innovations. In addition, the most important modification in the way traditional technological development in the field of medical engineering is currently accomplished is to systematically include those users in the design process for which the technology is planned. A coherent user-centered research of AAL technologies at home will result in an optimally designed medical technology, which is not only functional, but also addresses fundamental user needs in terms of appearance, ease of use, and last but not least privacy issues.

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