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Medical Technology in Smart Homes

Exploring the User's Perspective on Privacy, Intimacy and Trust

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***Abstract*—This paper reports on a study exploring the attitudes of users towards video-based monitoring systems for long-term care of elderly or disabled people in smart home environments. The focus of the study was on investigating the willingness of users to accept medical technology in their homes and the specific conditions under which continuous monitoring would be acceptable. Using the questionnaire method, a total of 165 users (17-95 years) were examined regarding privacy, intimacy and trust issues for medical technology in homes. The results highlight trust and privacy as central requirements, especially when implemented within private spaces. The reported concerns were mostly insensitive to gender and age. Overall, it was revealed that acceptance issues and users' needs and wants should be seriously considered in order to successfully design new medical technologies.**

Keywords-Medical Technologies, Smart Homes, Ambient Assisted Living, Technology Acceptance, User Study

I. INTRODUCTION

Prolonged life expectancy and increasing survival of acute diseases contribute to a growing number of elderly people at risk of institutionalization [1]. But long-term institutionalization is not only a big financial burden to the healthcare system and therefore hard to maintain in the coming years, it is also not the preferred choice of many aging people. While older people are obviously in need of extended long-term care, they also wish to maintain their independence as long as possible [3]. Studies show that many older people regard their home as a sanctuary and therefore prefer to stay at home, even at an increased risk to their health and safety [4]. This wish is often related to a perceived increase in the quality of life in a familiar environment. Generally, quality of life is a quite complex concept referring to the individual perception of one's "physical health, psychological state, level of independence, social relationships, personal beliefs and relationship to salient features in the environment" [5]. But as people age, their perceived quality of life is mostly determined by their ability to maintain an autonomous and independent life [6]. Hence, a variety of authors, including Bayer and Harper [7], Shafer [8], and Mynatt et al. [9], identified the loss of personal independence as a major concern of most elderly people.

While extended family structures traditionally provide internal support features for elderly family members, the analytic concept of extended families has largely diminished in recent years [10]. The profound social changes affecting the composition of families become especially evident in the growing number of elderly persons living alone. Already today, a high number of older or chronically ill people live on their own, without support by their families [12]. Over the last decades, the number of single households increased considerably, especially in the group of elderly people, and this trend is expected to continue in the coming years.

It is often argued that the steep increase in single households over the last years is caused by a transformation of the social structures in many western societies. But what goes largely unnoticed is the fact that elderly people often resist family assistance as they regard the exercise of familial obligations as an assault on their dignity and moral worth [13]. This is underlined by poll results, which suggest that about 95% of the older people did not wish to live with relatives [10]. Hence, the 'reciprocity thesis', which suggests that elderly people look after their children so that those same children will look after them in return, is actually contradicted by the strong resistance of elderly persons to accept help from younger family members [13].

II. VIDEO-BASED HOMECARE SOLUTIONS

Decreasing both the costs of healthcare services and also the load of medical practitioners requires a dramatic change in the way future healthcare services are provided [14]. A variety of medical experts [1] argue that institutionalization in senior homes is unnecessary (and even counterproductive) and promote homecare as a fundamental component of a future network of long-term care facilities. Recent developments in information and communication technology lay the groundwork for new patient-centered homecare solutions. While the majority of computer-supported healthcare tools designed in the last decades focused mainly on medical caregivers, this trend recently changed with the introduction of assistive technology for providing supportive and adaptive services to ill or disabled individuals [15]. Several authors, e.g. [1] or [16] even expect the next generation of healthcare systems to be mainly based on the

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homecare idea, thereby extending healthcare from the traditional hospital setting to the patient's home.

With an increased availability of broadband network connections and decreasing costs for networked cameras and large-scale displays, video-based homecare solutions are becoming an interesting alternative for a wide group of patients. From a technical point of view, most problems encountered in early telehealth systems are solved by now. Even low-cost systems provide high-resolution video images with low latency and offer a reliable infrastructure for medical monitoring and remote consultation [17]. But technical shortcomings were not the only problems identified in early video-based communication systems. Studies with existing prototype systems [18][19][20] revealed serious privacy concerns associated with the usage of continuous video connections, both in office and home settings.

III. MATERIALS AND METHODS

A. Overall Research Questions

While smart medical technologies bear the potential to revolutionize medical homecare, numerous studies showed that privacy is a highly crucial criterion for the acceptance of technology-enhanced environments. Many authors like, e.g., Hong and Landay [21], even regard privacy problems as the greatest barrier to the long-term success of smart homecare systems in general. This is circumstantiated by a variety of studies on different aspects of privacy in home environments. For example, in a survey by Privacy Rights Clearinghouse [22] participants indicated that privacy protection was more important to them than any potential benefits provided by ubiquitous computing applications [23]. Hence, privacy issues need to be explored in an early phase of the design process, if future home technologies are to become accepted by potential users [24].

The goal of this study is to explore attitudes towards the usage of video-based systems for long-term care of elderly or disabled people in smart home environments. Using an exploratory approach, we aimed at identifying the usage motives for as well as the barriers against these technologies. In order to understand the specificity of acceptance patterns, general attitudes towards technology were determined and related to the acceptance of medical technology. Furthermore, we wanted to find out, which of the reported arguments are more decisive than others and which of both, usage arguments or barriers are prominently impacting the intention to use video-based medical technology.

B. Methodology

Previous work showed that the acceptance of smart medical technologies in home environments is a rather complex phenomenon [25][26][27]. Therefore, an explorative approach was chosen to identify important factors influencing the adoption decision. To examine a large number of participants and at the same time address the high diversity of users, a scenario-based questionnaire method was used. The following medical scenario was presented to participants in order to introduce them to the field of video-based medical homecare applications:

"Imagine we live in the year 2030 and the majority of the population is 70 years or older. Many people will depend on medical assistance and/or personal care. Not all family members will be able to take care of their older relatives, as their jobs are keeping them busy or they are not living in the same area anymore. Recent technical developments could bear a big potential for providing age-sensitive medical support for older people in home environments. Already today there are technical solutions to install cameras and microphones in private homes for transmitting visual and audio data to medical personnel. In case of an emergency, like a fall or heart attack, this information would allow emergency services to assess the situation and initiate appropriate rescue actions. In addition, such technology could also be used by medical personnel to periodically check that everything is in order or for regular video-conferences between patients and their doctor."

With respect to the validity of the findings, it is of crucial importance, whether the public perception of trustful medical technology in home environments is examined with ill patients, or in healthy persons, who evaluate the acceptance of medical technology in a prospective manner. It is often argued that healthy persons cannot "feel" the necessity of medical technology, as they are not truly concerned. Despite this, there is a huge knowledge gap about the public discourse and potential ambivalence to technology-supported care concepts, in combination with attitudes, (social) trust in healthcare and technology. The understanding of individual beliefs is crucial as the public opinion considerably impacts the cognitive mind setting of future users. Therefore, we selected a comparably healthy sample of a wide age range for getting broader insights into user cognitions.

C. Variables

It was our aim to survey opinions across a diverse user group of a wide age range and to learn how they evaluate the suitability of video based systems, which would monitor health data at home. Within this scenario that people might live longer at home by help of technical solutions, we asked for privacy concerns and trust requirements of technical systems. As the age and the gender of participants could play a crucial role, we analyzed age and gender effects and treated both factors as independent variables. Regarding age, we contrasted four different age groups to get detailed insights (in section E age groups are described). In total, the data of 78 males and 87 females were compared. As dependent variables we surveyed (1) the general suitability of video-based systems for monitoring health data at home, (2) the importance of privacy issues, (3) the perceived trust in systems and (4) the discretion of technology in combination with the avoidance of stigmatization.

D. Questionnaire

In order to collect comprehensive opinions and to reflect them across a broader sample of women and men of different ages, we chose the questionnaire method. The items and sections used in the questionnaire were based on previous empirical work, where argumentation patterns from users of

a wide age range [28][29][30][31] were collected. The questionnaire was divided into five main sections.

(1) *Demographic data:* The first part included demographic data. Also, the users' *previous experiences* with different types of information and communication technologies (computer, internet, mobile, digital camera) were assessed.
(2) In section two, we collected opinions about the *general suitability of video-based systems,* implemented in home environments in order to monitor the health states of users. Table 1 shows the relevant items.

TABLE I. GENERAL SUITABILITY OF VIDEO-BASED SYSTEMS

Answer categories: yes / probably / probably not / no
• Would you be willing to let medical personnel monitor your home?
• The thought of ubiquitous medical support worries me, but I would accept it, if it could really help me.
• In order to get medical support, I would accept an intrusion in my personal privacy.

(3) In the third section, the *importance of privacy* was addressed. The relevant items can be found in Table 2.

TABLE II. IMPORTANCE OF PRIVACY

Answer categories: yes / probably / probably not / no
• Data protection must be fully guaranteed.
• Sensitive data, e.g., about medication or diseases, should only be transferred anonymously to physicians or pharmacists.
• It is important to me, that my data are protected by a password.

(4) The fourth section addressed questions about feelings of *trust*. Items can be found in Table 3.

TABLE III. TRUST

Answer categories: very strong, strong, low, very low
• I have concerns that third parties could illegally access data, which medical devices capture within the home.
• I fear that my data could be forwarded without my consent (e.g., to my employer or health insurance company).
• I fear that my data could be altered or deleted as a result of system malfunctions, like a sensor error or a computer virus.

(5) The fifth section dealt with *discretion of technology/avoidance of stigmatization* (Table 4)

TABLE IV. DISCRETION/AVOIDANCE OF STIGMATIZING

Answer categories: very important, important, not important, not at all important
• Cameras and microphones should be invisibly installed.
• Medical devices at home should be unobtrusive and not visibly to others.
• I do not want that others can see that I am depending on using medical technology

E. Participants

The data of N = 165 participants, 78 males and 87 females, aged between 17 and 95 years (46% female) were analyzed in this study (M = 47.9; SD = 18.7). In order to examine age effects, the sample was split into four age groups: the first group is aged between 17 and 30 years and consists of 35 persons (M = 23.3; SD = 3.7; 43% female), the second age group (N = 38) consists of males (53%) and females (47 %) of the age between 31 and 49 years (M = 41.6; SD = 7), and the third age group contains 46 respondents aged between 50 and 65 years (M = 57, SD = 4.3) with a proportion of 63% females and 27% males. Finally, the oldest age group (age group 4) includes 46 persons aged between 66 and 95 years of age (M = 72.5; SD = 7.4; 54% females).

The participants were reached on different ways. Most of the younger participants were university students (different disciplines). Other respondents in age groups two and three were reached through the social network of the authors' and seniors' social contacts. The oldest group was reached in senior homes. Overall, all participants had a solid experience with common ICT. Naturally though, the younger participants reported to be more familiar with these devices compared to the older participants (especially those over 70 years of age). Regarding gender, there was no difference in the reported frequency of using ICT.

IV. RESULTS

Results were analyzed by (M)ANOVA procedures. The level of significance was set at 10%. A first analysis addresses the general suitability of video-based systems, followed by the description of outcomes regarding perceived privacy and trust in these systems. Finally, the opinions regarding the discretion of technical systems and the avoidance of stigmatizing are described. In each of the sections we first describe the findings (means, standard deviations) for the whole sample, followed by comparative analyses within the different age and gender groups.

A. General Suitability of Video-Based Systems

Being asked whether participants would be generally willing to let medical personnel monitor their home, the whole sample answered with, on average, "probably not" (M = 1.4; SD = 0.9). No gender differences were found. Both, males and females, showed the same reluctance, when answering, "probably not" (females: M = 1.5; males: M = 1.4). When looking at age, the youngest group (17-30 years) was most reluctant compared to all other age groups, though the difference was not statistically significant (Fig. 1).

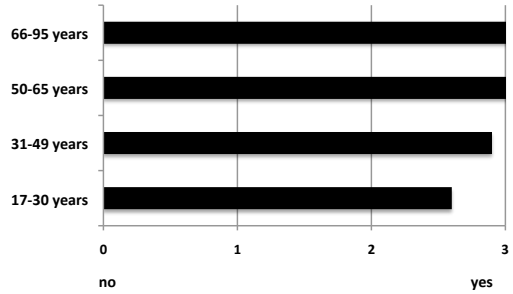

Figure 1. Would you be willing to let medical personnel monitor your home? (no = 0, probably not = 1, probably = 2, yes = 3), N = 165

The next question aimed at a conditional acceptance of video-based monitoring systems. Participants had to answer whether they would accept video-based monitoring systems, if they would really help them. Participants answered with "probably, yes" (M = 3; SD = 0.8). The assessment was identical for both genders (M = 2.98), but was significantly modulated by age (F (3,408) = 2.4; p = .055) (Fig. 2).

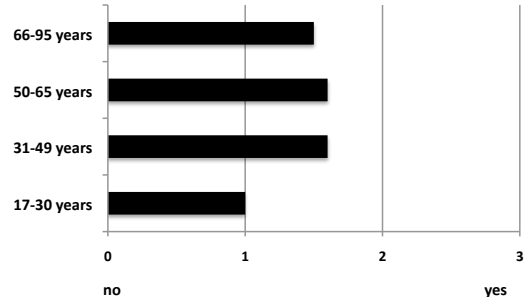

Figure 2. The thought of ubiquitous medical support worries me, but I would accept it, if it could really help me (no = 0, probably not = 1, probably = 2, yes = 3), N = 165

The last question within this section that had to be answered was whether participants would allow an intrusion within their private sphere in order to be medically supported. Overall, participants reacted quite indifferently, ranging between "probably not" and "probably" (M = 2.5; SD = 0.95). It is an interesting finding that age and gender did not show linear trends in this question (marginal significant interaction, F (3,136) = 2.2; p < 0.1). As shown in Figure 3, women would accept an intrusion within their private sphere more willingly with increasing age in contrast to men, which are more reluctant with the older they were.

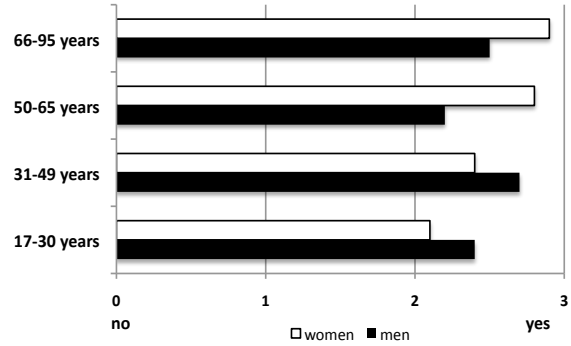

Figure 3. In order to get medical support, I would accept an intrusion in my personal privacy (no = 0, probably not = 1, probably = 2, yes = 3). White bars represent female, black bars male respondents. N = 165

B. Importance of Privacy

With regard to the question whether data protection must be fully guaranteed, there was a clear answer (with no differences of age and gender). Apparently, data protection is not only an explicit requirement, but also seems to be a strong universal claim (M = 3.9 out of 4 points max., SD = 0.5). Regarding the handling of sensitive data, participants strongly agreed that medical data should only be transferred anonymously to physicians or pharmacists (M = 3.4, SD = 0.9), revealing no age and gender differences. We also asked for the importance of personal data protection with passwords. Again, answers were clear across the whole sample: all participants, independently of age and gender, attached great importance to password protection (M = 3.4; SD = 0.9). Even if one could have expected that data protection would be less important for the very old group – as they have a lower technical literacy and the higher need to use these technologies – this was not the case.

C. Feelings of Trust

Beyond privacy and security issues, the emotional component of trust plays an important role in the adoption process. Participants had to rate their fears (illegal access, data transfer without consent and data loss due technical malfunctions). As shown in Fig. 4, the extent of fear is quite high in all three cases. Interestingly, the fear that data could be altered or deleted as a result of system malfunctions, like sensor errors or computer viruses is most pronounced, followed by the fear of data delivery without consent and the fear of illegal access. These ratings represent the opinion of the whole sample, without any statistically significant differences of gender and age.

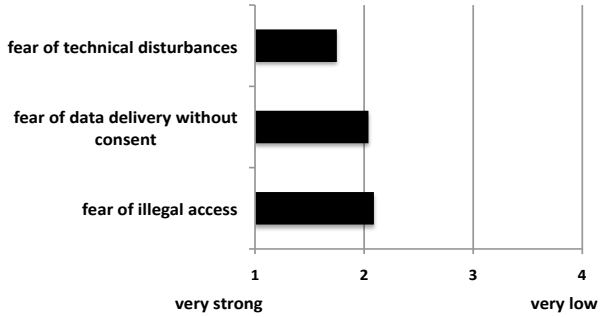

Figure 4. Descriptive outcomes regarding the reported fear of illegal data access, the fear of data delivery without consent and data loss due to technical malfunctions (1 = very strong; 4 = very low). N = 165

D. Discretion and Avoidance of Stigmatization

Finally, we asked for the importance of discretion and the avoidance of personal stigmatization (Fig. 5).

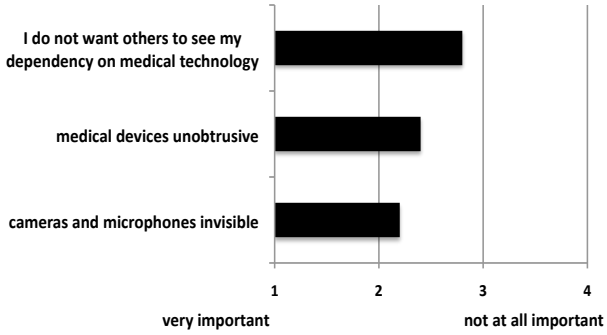

Figure 5. Outcomes regarding the reported fear of illegal data access, the fear of data delivery without consent and data loss due to technical disturbances (1 = very important; 4 = not at all important), N = 165

The most important issue is that cameras and microphones are invisibly installed in home environments (M = 2.2; SD = 0.9), followed by unobtrusive and invisibly medical devices (M = 2.4; SD = 1). The fact that others could see that participants need to be supported by medical technology, though, is rated as not so important (M = 2.8; SD = 0.9). The attitudes were not impacted differentially by age and gender, revealing a very universal public perception.

V. DISCUSSION

In contrast to a detailed and rich level of awareness regarding factors of technology acceptance in the information and communication sector, only very limited knowledge is prevalent about the specificity of technology acceptance in medical homecare scenarios, especially regarding privacy, intimacy and trust perceptions. This lack of knowledge is precarious, when considering the upcoming need for medical technology in the homecare sector and when facing the demographic change and the upcoming societal shortcomings regarding economic, structural and personal resources.

In general, we corroborated a quite critical view on the acceptance of smart medical systems at home. Participants reported to be unsecure about the trustfulness of these systems and fear illegal data transfer, access and also that personal data could be altered or get lost due to technical problems. When asked whether respondents would be generally willing to accept medical technology that monitors health states at home, answers were quite critical and reluctant. Only if it is fully guaranteed that these systems do not only respect privacy limits, but are also unobtrusive and invisible and do provide a true support, a reasonable acceptance level can be expected. It is remarkable that – beyond some singular age effects – age mostly did not impact the reported attitudes. In contrast to outcomes in many other fields of technology usage (see, e.g., [28], [29] or [30]), in which there are remarkable differences between younger and older adults, this is not the case in this context. This shows that the different cognitive mindsets of technology of older adults as well as their lower technical expertise, formed by a different upbringing and technology generation, are not the crucial player for acceptance outcomes here. Instead, to our perspective, the chariness and reluctance are due to two major sources. One is the novelty of smart home technology and the difficulty for participants to imagine how medical technology could affect normal living at home. In such cases, the reluctance is not literally a refusal to use these systems, but more probably a global insecurity of how these systems work and an uncertainty whether these systems bring more negative effects than benefits. The second factor is that people are very clairaudient whenever technology come into private spheres, at least in this sensitive context, in which technology enters core fields (body, home, family, health). We all know the public discussion about data safety and data security and the sometimes hysterical and lurid press coverage of privacy protection within the public media. Even though it is naturally a high value that personal data are treated with caution, respect, dignity and intimacy, any undifferentiated public discussion fails to reach one important goal: A fair and objective information and communication about benefits and risks and the sensitive trade-off between both poles. To date, we do not have a specific information and communication concept for medical technologies, not to mention any awareness that there is a considerable need for this. On the one hand, only little knowledge about real benefits and, also, problems of medical smart home technologies are prevalent in the public discourse. On the other hand, system designers seem to believe that especially aged persons will automatically and easily accept medical technology out of pragmatic reasons and that no detailed information about the usage conditions and consequences is needed. It seems to be a common belief that persons must want to use medical devices in order to keep their independence and mobility, and that they will use this technology anyway, as they do not have alternatives. Considering that “aging” and “illness” entail different development processes, attitudes, and biographical influences, this assumption seems ignorant. People developing medical technology should take respondents’ rather reluctant attitude in this regard seriously.

From a psychological point of view, it is quite astounding how strongly public concerns about the feeling of being monitored by technology and the perceived risks regarding data safety and data protection differ depending on the usage context of technology and the respective application field, in which these technologies are implemented. We all are quite inattentive about risks of data security and the ability of mobile phones to accurately localize the position of people. Instead, we focus on the social values associated with these devices, like brand, prize, device novelty or the richness of functionalities. In addition, we often handle passwords and data protection quite recklessly. As passwords are not easy to remember, many people never change their passwords and often use one and the same password across multiple devices. While this makes daily life a lot easier it also increases the risk of illegal data access by third parties. In direct contrast, people report to be very sensitive and critical whenever mobile technology or smart medical technology enters their homes. Apparently, the cognitions and the emotional evaluation are modulated to a lesser extent by the kind and the specific characteristics of technology (which is the very same in both usage contexts), but rather by the trustworthiness of technology, which is subjectively accredited to the respective usage or situational context [31][32].

Naturally, this research is limited to a specific country and technology culture. But of course, any study dealing with technology acceptance is related to the cultural view on aging, diseases and also the value to have or use technology. Future studies will have to explore the public perceptions of smart homecare technologies in other culture.

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