Acceptance of Pervasive Healthcare Systems: A Comparison of Different Implementation Concepts

Martina Ziefle, Carsten Röcker
Communication Science, Human Technology Centre (HumTec)
RWTH Aachen University
Theaterplatz 14, 52056 Aachen, Germany
{ziefle, roecker}@humtec.rwth-aachen.de

Abstract—**While pervasive healthcare systems bear the potential to provide patients with a new quality of medical homecare, the complexity of such systems raises fundamental questions of behavior, communication and technology acceptance. This is especially important, as users of future healthcare systems will be increasingly characterized by diversity. Relying only on highly experienced and technology-prone user groups, which might have been typical users in the last decades, is not sufficient anymore. Rather, elderly users, users with a completely different upbringing and domain knowledge, and ill or handicapped people will have to use the systems. Today, the understanding, in which way physical, emotional and cognitive abilities, caused by individual learning histories and health states, may impact the usage and acceptance of pervasive healthcare technologies, is restricted. This research contributes to this topic by investigating the acceptance motives of aged users with different health states regarding three different implementation concepts for medical technologies: medical technology implemented in mobile devices, smart environments and smart clothing. Using the questionnaire method, a total of 82 users between 40 and 92 years of age were examined regarding their usage motives and barriers with respect to the different technology concepts. Overall, it was revealed that acceptance issues and users' needs and wants should be considered in order to successfully design new medical technologies.**

Keywords - Pervasive and Ubiquitous Computing, Ambient Assisted Living, Technology Acceptance, Health, Study.

I. INTRODUCTION

Within the last five to ten years a variety of new healthcare concepts for supporting and assisting users in technology-enhanced environments emerged [16] [26]. These so-called pervasive healthcare applications open up new possibilities for supporting diagnosis and therapy, by bridging temporal and spatial gaps between patients and physicians. Modern information and communication technologies (ICT) enable autonomous and unobtrusive collection of clinical data and support the continuous transmission of physiological information between patients and remote healthcare providers [19]. For patients with chronic diseases, like, e.g., chronic heart failures or diabetes, pervasive healthcare systems help to minimize hospital stays and in doing so enable an independent life in a domestic environment.

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II. TECHNICAL APPROACHES TO PERVASIVE HEALTHCARE

Pervasive healthcare systems are designed to provide different types of medical services and to support users *individually* (according to user profiles), *adaptively* (according to the course of disease) and *sensitively* (according to living conditions) [34]. While the overall objectives are usually the same in most systems, the technical approaches taken to achieve these goals vary widely. Looking at state-of-the-art research prototypes reveals three basic realization concepts with varying degrees of embeddedness.

A. Smart Artefacts and Mobile Devices

The most popular approach is to use dedicated mobile devices or so-called "smart objects" in order to provide context adapted services independently of the patient's current location. Smart artifacts are technology-enhanced everyday objects, which are equipped with sensors, memory and communication capabilities (see, e.g., [8] or [11]) and which are able to capture information about their surrounding, communicate with each other and react according to previously defined rules [25]. Through the capability to interact with humans directly, they can help users to accomplish different tasks in new, intuitive ways [3]. Examples for such systems include Smart Pillow [23], Smart Sofa [18], Smart Dishes [5]. Other pervasive healthcare applications like, Vitaphone [27] or Dr. Feelgood [21], use existing electronic devices, like mobile phones or PDAs, for providing their services. In contrast to smart objects, such devices provide extensive information processing and communication capabilities, but lack the physical component, which serves another purpose than the functionality implemented in the digital part [9].

B. Wearables

Instead of additional mobile devices that have to be intentionally taken, the concept of 'wearable computing' envisions computers to an integral part of our everyday clothing. The goal is to have an always-on and networked computational artifact that assists mobile users a wide range of everyday situations. Following this idea, several projects integrated communications and sensor technologies into a broad variety of clothes, including shoes [15], shirts [14] [20], and belts [24], as well as jewelry [2]and wrist watches [31].

C. Smart Environments

Based on the initial idea of Ubiquitous Computing [28], the concept of 'smart environments' envisions a future, where a multitude of computers are seamlessly embedded into the physical surrounding. While smart environments were traditionally developed for supporting users' in the work domain, today's research activities mainly focus on intelligent home environments for assisting elderly and ill people [34]. Existing prototype systems vary widely regarding their degree "smartness" and the assistance they offer, and range from single rooms [4] to entire houses [17].

III. Motivation and Goal

While pervasive healthcare systems bear the potential to provide patients with a new quality of medical homecare, the complexity of such systems raises fundamental questions of behavior, communication and technology acceptance. For example, users of future healthcare systems will be increasingly characterized by diversity. Relying only on highly experienced and technology-prone user groups, which might have been typical users in the last decades, is not sufficient anymore (see [6] or [7]). Rather, elderly users, users with a completely different upbringing and domain knowledge, and ill or handicapped people will have to use the systems. As previous research focused mainly on information and communication technologies [1] [32] [33], there is a major need to understand in which way physical, emotional and cognitive abilities, caused by individual learning histories and health states, may impact the usage and acceptance of pervasive healthcare technologies [12] [13] [22].

The main goal of our research was to analyze the contribution of individual factors on acceptance patterns in different implementation concepts. Therefore, we selected three different solutions for the implementation of medical technologies: 1) smart home environments, (2) smart clothes, and (3) mobile devices like, e.g., mobile phones. For each of these implementation concepts, we assessed the different usage motives. To compare the concepts, a part of the items was identical (see description of items in section III C), while other items, addressed specific characteristics of the respective technology in order to learn the technology-dependent specificity of the acceptance patterns.

Among individual factors, which might impact the acceptance of these technologies, we examined the influence of users' age (ranging from 40 - 92 years of age), but also the impact of gender as well as the health states of participants. The latter accounted for the fact that acceptance patterns could be considerably modulated by frail persons' closeness to the need of medical technology. In short, the following questions guided our research:

1. Can acceptance patterns of different implementation concepts be distinguished?
2. Which are the design requirements for specific implementation concepts (mobile devices, wearables, smart environments)?
3. To which extent do individual factors (gender, age, health status) influence adoption decision?

IV. Method

We assume the acceptance of (smart) medical technology to be a rather complex phenomenon. In order to learn, which components might be decisive for the forming of technology acceptance toward medical technology, we used an investigative and explorative approach.

In order to examine a large number of participants and to consider the diversity within the group of elderly users, the questionnaire method in combination with a scenario technique was chosen as an empirical approach. Participants were introduced to a medical scenario:

> "Imagine that in the year 2025 a vast majority of people in our society are 65 years and older. Many of these people will be frail and therefore reliant on medical care. Due to shortcomings in the care sector (economic bottlenecks and a decreasing number of nursing staff) it is a basic question how older people can live independently at home, and have access to medical services. Yet, there are already mature technical developments, which enable continuous medical care at home".

It was instructed that each of the three concepts (smart home, smart clothes, and mobile devices) would allow online monitoring of bio signals, an automatic communication with the doctor and medical staff and, if necessary, the immediate and automatic contact to an emergency ambulance. Participants were requested to envision the use of such a device and implementation concept, respectively, and to evaluate, if it may be helpful for them, to state if they would accept technologies like these and to report the most important pros and cons regarding the usefulness of these technologies.

A. Variables

As *independent variables* participants' age (comparing three different age groups) and gender (contrasting female and male respondents) were taken into consideration in the present study. Also, the health status of participants was considered (as indicated by participants). *Dependent variables* were the usage motives and barriers within the three technology types and implementation concepts.

B. Questionnaire

In order to collect comprehensive opinions and to reflect them according to generations we examined a large number of participants choosing the questionnaire method. The questionnaire was arranged in three main sections. The first part included demographic data regarding participants' age, gender, educational level and health status. The second section addressed the participants' experience with and attitude towards technology. The experience, the usage frequency of common ICT devices (e.g., mobile phone, PC, video/digital camera, navigation system), and the perceived usability of these devices were assessed. In addition, we asked for the usage frequency of different medical devices (blood pressure meter, pulse monitor, hearing aid, in-house emergency system). The third section explored the acceptance motives of the different implementation concepts. Specifically, we asked for the usage conditions, which should be given for voluntary use of the respective technology. Statements were taken from

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previous research of our work group [10] [29] [30], in which focus groups with older adults were conducted and the main arguments in both, pros and cons were collected. The items are referred to five dimensions: ease of use, inconspicuousness, aesthetics/design, control, and communication comfort. In Table 1, the items regarding the usage conditions are visualized, which were identical in all technology concepts.

TABLE I. USAGE CONDITIONS TO BE ACHIEVED BEFORE THE TECHNOLOGY CONCEPT WOULD BE ACCEPTED FOR PERSONAL USE (APPLICABLE FOR ALL TECHNOLOGY CONCEPTS).

Would you be generally willing to use medical technology Likert scale: yes / probably yes / probably no / no
… integrated in the home.
… integrated in smart clothing.
… integrated in a mobile device .
Essential conditions for the usage of smart home, clothing, mobile device Likert scale: very important/quite important/quite unimportant/not important
… if the usage is really easy (ease of use).
… if the technology cannot be recognized as medical (inconspicuousness).
… if the technology has an appealing design (aesthetics).
… if I could control the transmission of the data (control).
… if communicating with the device is easy (communication comfort).

As each of the tested implementation concepts has specific characteristics and is therefore likely to provoke different acceptance patterns, we also included items, which were specific for the respective concepts (Table 2 shows the results for smart homes, Table 3 for smart clothes, and Table 3 for mobile device).

TABLE II. USAGE CONDITIONS TO BE ACHIEVED BEFORE THE SMART HOME TECHNOLOGIES WOULD BE ACCEPTED FOR PERSONAL USE

Essential conditions for the usage of smart home Likert scale: very important/quite important/quite unimportant/not important
… if the technology would recognize me and know exactly what I need (context adaptivity).

TABLE III. USAGE CONDITIONS TO BE ACHIEVED BEFORE SMART CLOTHES WOULD BE ACCEPTED FOR PERSONAL USE

Essential conditions for the usage of smart clothing Likert scale: very important/quite important/quite unimportant/not important
… if the wearing comfort would be high (comfort).
… if the smart clothes would not constrain me (mobility).

TABLE IV. USAGE CONDITIONS TO BE ACHIEVED BEFORE THE MEDICAL TECHNOLOGY IMPLEMENTED IN MOBILE DEVICES WOULD BE ACCEPTED FOR PERSONAL USE

Essential conditions for the usage of mobile devices Likert scale: very important/quite important/quite unimportant/not important
… if I had a separate device or medical functions (distinctness).
… if medical functions are integrated into an existing device (simplicity).
… if the device would be tiny and light weight (physical affordances).
… if the mobile device would be personalized (intimacy).

Before administering the questionnaire it was revised by a sample of differently aged adults and by a usability expert with respect to issues of comprehensibility and wording of items. Filling out the final version of the questionnaire took between 20 and 40 minutes, depending on the age and frailness of the participants.

C. *Participants*

The data of N = 82 participants, aged between 40 and 92 years were analyzed in this study. The intention in the recruitment procedure was to survey users of a wide age range and health status in order to explore and to compare their motives and barriers about future healthcare solutions. The sample was split in three age groups: the first group is aged between 40 and 50 years (M = 45.5, SD = 4.1, 55% female), the second age group (N = 35) compose males (43%) and females (57%) at the age between 51 and 65 years (M = 58.6, SD = 4.5), and the third age group contains 40 respondents aged between 66 and 92 years (M = 74.1, SD = 6.8) with the proportion of 55% females and 45% males. Respondents were reached partially through the authors' social networks as well as through seniors' social contacts, and covered a broad range of professions and educational levels. With regard to the health status, 39 out of 82 persons (53% male, 47% female) stated to suffer from a chronic disease (unknown source).

V. RESULTS

Outcomes were analyzed by (M)ANOVA testing procedures in order to reveal differences between age groups/generations, gender and health states on acceptance patterns. In addition, understanding the relation between variables bivariate correlations were run. The level of significance was set at 5%. Results within the less restrictive significance level of 10% are referred to as marginally significant. The result section is structured as follows. A first analysis addresses the question, whether effects of age, gender and health states on the evaluation of the usage conditions and acceptance patterns can be identified. Then, interrelations of experience with technology, medical technology, age and gender are detailed.

A. *General willingness to use medical technology integrated into smart homes, smart clothes or mobile devices*

A first analysis considers the question if participants are basically willing to use the respective technology (Figure 1).

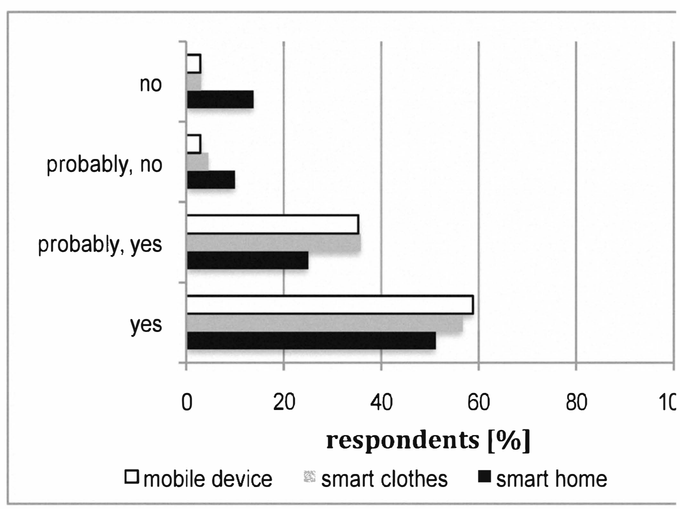

Figure 1. General willingness to use medical technogy (N = 82)

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As shown in Figure 1, there are distinct differences respecting the general willingness to use medical technology within the respective implementation concept. Smart home technology is basically evaluated more critically than smart clothes and mobile devices, which can be taken from the fact that 14% of respondents completely reject to use medical technology integrated in homes, in comparison to 3% for smart clothes and mobile devices. The highest confirmation was observed when medical technology is implemented in mobile devices (nearly 60%, in contrast to 56% for smart clothes, and 51% for smart homes). Regarding acceptance patterns and acceptance facets, which form the overall intention to use, it is striking that the extent of confirmation to use these technologies is to a lower degree influenced by the three implementation types than by the question whether participants would use these technologies at all. Apparently, users have a principle attitude for or against the willingness to accept future medical technology than a specific preference to one or another type of technological approach.

Overall, there is a high interrelation of the general willingness to use the respective technologies across the different implementation concepts. As taken from correlation analyses, individuals, who are willing to use the one technology, are also positive towards the usage of the other technology (smart home/smart clothes: $r = 0.43$; $p < 0.01$; smart home/mobile device: $r = 0.44$, $p<0.01$; smart clothes/mobile device: $r = 0.54$; $p<0.000$).

In contrast to our expectations, neither age nor gender did impact the overall willingness to use these devices, independently from the respective technology type. Interestingly, not even the health status of participants showed significant interrelations.

Comprising the outcomes so far, the general willingness to use or not to use medical technology is less impacted by user diversity (age groups, gender, health states), but by the specific technology approach. Here, medical technologies implemented in smart homes are evaluated most critical while medical technologies integrated in mobile devices are perceived as most positive.

B. *Usage criteria, which are essential in order to use medical technology integrated in smart homes, smart clothes or mobile devices*

This section addresses the different conditions, which had to be achieved before participants would use the respective technologies. Overall, we asked for the importance of the ease of use, inconspicuousness, controllability, aesthetics/design, and communication comfort.

For each usage criterion, the descriptive findings are reported, followed by a description of the impact of user diversity (age, gender, health states) on evaluation outcomes.

Ease of Use: Generally, the ease of use is a "very important" criterion (smart home: 69%; smart clothes: 63%, mobile device 62%). In contrast, only a small percentage of respondents evaluated the ease of use as "not important" (smart home: 5,2%; smart clothes: 1.4%, mobile device 2,6%). MANOVA analyses (omnibus effects) showed that the ease of use was significantly impacted by age ($F(6,102) = 2.2$; $p<0.05$) and gender ($F(3,102) = 2.5$; $p<0.05$). In contrast, the health status did not affect ease of use evaluation. When focusing on the different technology types, gender effects on ease of use evaluation were significant in mobile devices ($F(1,80) = 4.4$; $p<0.05$) and for smart home technologies ($F(1,80) = 5.8$; $p<0.05$). In both technology types, female respondents evaluated the ease of using these technologies as more important than male respondents. Age specifically impacted the ease of use evaluation in mobile devices ($F(2,80) = 7.5$; $p<0.05$) – with increasing age, ease of use is rated more important. The latter is especially pronounced for mobile devices, which might be due to the fact that older adults do have some negative experiences when using mobile devices [1] [32].

Inconspicuousness: The inconspicuousness of medical technology is not perceived as a key criterion, in neither of the tested technology types. Across all participants, the most frequent answer was "not so important". For smart home technologies, 64% of the respondents evaluated the inconspicuousness as "not so important" or even "unimportant". A similar pattern was observed in mobile devices ("not so important": 48% of respondents; "unimportant": 22%) and in smart clothes ("not so important": 42% of respondents; "unimportant": 15%). It is an interesting finding that the importance of the inconspicuousness of medical technologies is not affected by user diversity, neither by age, nor by gender and by health states of respondents). Thus, for medical devices inconspicuousness of medical technology and the fear of shame are not so prominent, across all users.

Controllability: Another criterion, which had to be evaluated by participants, was the controllability of data (control of data transmission). It is insightful that - irrespective of age, gender and health states as well as irrespective of the technology concept (smart home, smart clothes, or mobile devices) - controllability is a key criterion of future medical technologies. The majority of respondents evaluated this criterion as "very important" (smart home: 46%; smart clothes: 46%; mobile devices: 49%) or at least "important" (smart home: 38%; smart clothes: 35%; mobile devices: 35%). Thus, people seem to have an unspecific uneasy feeling and concerns about data security and the loss of control.

Aesthetics/Design: Contrary to other technological fields (automotive technology, information and communication technologies) and contrary to stereotypes, according to which at least gender would significantly impact the demand for an appealing design, this was not the case here. Respondents (irrespective of individual factors) evaluated the design of future medical technologies as "not so important" (smart home: 28%; smart clothes: 33%; mobile devices: 36%) or even "unimportant" (smart home: 25%; smart clothes: 21%; mobile devices: 28%).

Communication Comfort: A final question addressed the ease of technical communication provided by the respective technology types. Technical communication is perceived as a key criterion. Irrespective of the type of technology delivering medical functionality, respondents evaluated the ease of communicating as "very important" (smart home: 39%; smart clothes: 43%; mobile devices: 35%) or at least "important" (smart home: 35%; smart clothes: 38%; mobile device: 42%). While there was no significant main effect of age, gender and

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health states, a significant interacting effect of age x gender was revealed ($F(6,102) = 2.3$; $p<0.05$). The interacting effect shows that with increasing age women evaluated the importance of the ease of communication with the technology as more important than male respondents.

C. Technology-Specific Usage Criteria

In addition, technology specific items were examined. Regarding *smart home* technologies, the ability of smart home technologies to individually react to individual demands and to adapt to personal needs is evaluated as "very important" by 30% or at least as "important" by 51% of respondents. Though, it should be noted that, still, 7% evaluated this criterion as not important at all. Again, user diversity did not impact these judgments.

With respect to *smart clothes*, the item "wearing comfort" was, overall, the most decisive characteristic of wearables. 65% of participants (irrespective of individual factors) evaluated the wearing comfort as "very important" and 32% as "important".

Finally, for *mobile devices*, we wanted to know whether the integration of medical functionality into an existing device (e.g., mobile phone) is more preferable for participants than to have an extra device, which exclusively handles medical information. Interestingly, there was no clear picture. Participants revealed to be rather unclear, which of both alternatives is more preferable. When looking into effects of user diversity, age revealed to be a distinctive variable ($F(2,80) = 3$; $p<0.05$). The older users are, the more they prefer an extra device delivering medical technology, while younger users (40-50 years of age) stated to prefer a combined device. Another age difference regarded the question if medical mobile devices should be personalized and specifically directed to individual user profiles. Older adults (60+ and 70+ years of age) evaluated personalized devices as less important than middle-aged adults (40+ years).

VI. Discussion

The aim of the present study was to investigate acceptance patterns and specific using characteristics in new medical technologies. In recent years, a variety of new healthcare concepts for supporting and assisting users in technology-enhanced environments emerged. The acceptance and usage conditions of medical technology implemented in mobile devices, smart environments, or smart clothing were under study. It was of specific impact if user diversity - in terms of age, gender, and health status - would have a significant impact on the evaluation of these technological concepts. Using the questionnaire method, a total of 82 users of a broad age range (40 - 92 years) were examined regarding usage motives and barriers. Findings are now discussed with respect to their implications for research, application design and future research demands.

First of all, it should be stressed that respondents' general willingness to use medical technology – if necessary – differs depending on the respective type of technology. Medical technology, integrated into home environments, seems to be more critically evaluated than smart clothing or mobile devices. It is an interesting finding that user diversity does not play a major role in this context. Though, there is a high interrelation of the general willingness to use the respective technologies across implementation concepts.

When looking at the different usage conditions and their respective importance, we identified the ease of using medical technology, the controllability of data, as well as the communication comfort with technology as the most decisive criteria, independently of the technology type, and quite independently of users' ages, gender and health states.

Thus, we can conclude that these criteria might be classified as a kind of universal characteristics that should be considered with respect to user-centered designs of future medical technology. On the other hand, we also identified insignificant criteria for medical technology: participants evaluated the inconspicuousness of technology and aesthetic or design features to be less important. Both characteristics are known to play an important role in ICT (e.g., Apple designs) or the automotive sector, in which drivers attach huge importance to form factors, color, sound or haptic features within the design of automotives. Possibly, medical technology is evaluated qualitatively as different – due to the fact that medical technology is of vital importance and its usage not voluntary. Another explanation might be that older persons show a different preference in contrast to younger adults, which had been mostly examined in previous studies. This should be addressed in future studies.

In contrast to previous studies, in which user diversity had been revealed as a major factor impacting both, the acceptance of ICT as well as the performance when using ICT devices [1] [6] [10] [29] [32], in this study user diversity played a minor role in the evaluation of needs and wants respecting future medical technologies. This is an astounding finding, especially with respect to the influence of different ages, and health states. One could have expected that the perceived closeness to use and need medical technology would have changed the demands regarding usability, intimacy and design. This was not the case. Apparently, the design and implementation of medical technology follows more strongly universal rather than differential individual demands.

VII. Outlook and Future Research

However, this study represents only a first insight into a highly complex phenomenon. Thus, there are limitations of this research, which should be picked up in further studies.

The individual decision for or against a specific technology type or implementation concept delivering medical technology depends on many more factors that should be empirically addressed in future studies. For example, the individual living situation, the economic situation as well as individual ageing and living concepts might be of interest. In addition, an insight into demands of intimacy or privacy in different living spaces (intimacy demands in different types of rooms, e.g., bedrooms, living rooms, or bathrooms) should be addressed.

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