Perceived Usefulness of Assistive Technologies and Electronic Services for Ambient Assisted Living

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***Abstract*—This paper reports on a study analyzing the attitudes of users towards different types of Ambient Assisted Living (AAL) services. The study explores the acceptance and terms of use of large interactive screens for the most common applications types: health, social and convenience services. In order to understand the impact of user diversity, we explored age, gender, health status, social contact, interest in technology, and the reported ease of use as well as their relation to acceptance. Using the questionnaire method, 30 women and 30 men between 17-95 years were examined. The results show that users are not yet very familiar with the vision of smart technology at home and report a considerable diffidence and aloofness towards using such technologies. Persons with many social contacts and a high interest in technology show the highest acceptance for electronic services at home. Astonishingly, the results for the different applications were insensitive to gender and age, which indicates that the precautious attitude towards AAL applications represents a universal phenomenon. Consequently, acceptance criteria as well as users' needs and wants should be seriously considered in order to successfully design smart home technologies.**

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

I. AMBIENT ASSISTED LIVING

Ambient Assisted Living (AAL) environments mark a big step towards enhanced quality of life for elderly and disabled people at home [1]. By reducing the need of caretakers, personal nursing services or the transfer to nursing homes, AAL environments can improve the daily life of elderly people and enable them to grow old at home [2] [3] [4]. Maintaining independent as long as possible and of not becoming "a burden" to family members is widely accepted as the major contributing factor to quality of life in old age [5] [6] [7]. Studies also show [8] that patients receiving home care are more likely to show positive attitudes in terms of satisfaction compared to patients receiving traditional care. Similarly, it is argued that people living in nursing homes tend to require more hospitalizations and doctor visits, and are more likely to suffer from depressions due to their lack of independence [5]. In addition, patients' privacy and dignity are enhanced by providing medical services in the patient's own homes [9] [10]. Consequently, AAL applications also positively contribute to an increased self-esteem of frail persons. Recent studies underline the importance of personal independence by showing a relation between reduced mobility and reduced self-esteem [11] [12]. In this context, assistive technologies can play an important role in enabling older or ill people to perform everyday tasks by accommodating individual weaknesses and renewing their confidence.

Over the last decade, a variety of prototype environments have been developed, both in industry and academia. One of the earlier systems is the *Aware Home* [13], an intelligent home environment equipped with different sensors capturing the state of the environment and its inhabitants. A similar approach was taken with the *Philips CareLab*. Another example is the *Intelligent Sweet Home*, a roboter-equipped smart house, which is based on several robotic agents and aims at testing advanced concepts for independent living with seniors [3]. Other examples of assistive environments include the *Gator Tech Smart House* [14], the *MavHome* [15], the *Microsoft eHome* [16], the *House of Matilda* [17], or *the Future Care Lab* [18].

II. ASSISTIVE TECHNOLOGIES AND ELECTRONIC SERVICES IN AAL ENVIRONMENTS

By providing a wide variety of services, AAL environments bear the potential of bringing medical, social and economical benefits to different stakeholders. While early systems were limited to purely medical functionalities, the range of services was continuously extended over the last years. Today's systems offer a multitude of functionalities including assistance to carry out daily activities, health and activity monitoring, enhancing safety and security, getting access to social, medical and emergency systems, and facilitating social contacts [4]. On a conceptual level, the majority of AAL applications can be clustered into three domains: medical and health services, communications services and conveniences services for everyday activities.

A. Medical Services

Medical services still make up the largest proportion of AAL applications. Existing systems mainly focus on the detection and prevention of emergency situations, long-term treatment of chronic diseases, and the prevention and early-detection of illnesses. Already today, several companies offer mobile systems, which enable users to call for help in case of an emergency. Commercial products, usually in form of mobile devices worn either at the hip or around the wrist, are available on the market. The majority of research prototypes for assistive services concentrate on patients with diabetes, heart diseases, memory loss or physical impairments [19] [20]. Intelligent homecare services for the prevention and early-detection of illnesses are mostly based on real-time information about the

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patients' physiological states and activities. In many cases the systems are based on wearable non-invasive diagnostic tools, which are capable of analyzing human sweat, tears, stress, strain, or pH increases [19]. For example, a medical monitoring and alert wrist device was developed [21], which continuously monitors vital data such as ECG, heart rate, blood pressure, and skin temperature. A number of similar ECG monitoring systems have been developed [8][10][22].

B. Communication Services

As people age and become less mobile, meeting other people outside the own home becomes more and more complicated if not impossible [11]. The resulting erosion of social networks is a natural consequence experienced by many older people [9], which is especially severe as social relationships are widely acknowledged as an important factor to well-being in old age [2] [23] [24]. Hence, it is important to provide seniors with adequate information and communication technologies, which enable them remaining integrated in social life, despite of ageing and disabilities [25].

A broad variety of projects addressed this challenge by designing smart awareness systems, which make use of context-sensitive services to facilitate lightweight, informal and emotional forms of communication in Ambient Assisted Living environments [26]. While ambient displays, by their nature, are not limited to certain kinds of data, most systems map presence information associated with other people to artifacts, situated or integrated in the environment [27]. For example, *Social Radio* [28], is an intelligent, multi-device awareness system for supporting emotional communication in small intimate groups in home environments. The system uses music and ambient light to provide light-weight information about the presence and mood of remote persons. Another tool for supporting intimate communication is the *Kiss Communicator* [29]. Blowing on the device creates ripples of light that can be sent to a remote partner's device, once a desirable pattern has been achieved. *Lumitouch* [30] and *The Bench* [31] are other examples of tangible interactive displays for supporting intimate communication.

C. Convenience Services for Everyday Activities

There is also a considerable body of research on AAL applications for supporting users in everyday activities by compensating for individual physical disabilities. For example, the *Input Adapter Tool* developed [32] automatically modifies the interfaces of JAVA-based applications in order to improve accessibility for users with restricted motor abilities. A similar system for web pages had been developed [32]. Jung et al. [7] developed a smart bed, which is able to 'sense' the intention of a user and act accordingly. Based on integrated pressure sensors, the bed is able to detect intended movements and automatically changes posture according to users' intentions [33]. More artistic systems include *EyeDraw* [34], which creates paintings based on users' eye movement or *VoiceDraw* [35], which converts voice signals into paint strokes.

Another widely explored approach for supporting users in everyday activities are gesture interfaces. With the *Gesture Pendant* [38], a wireless device enables users to control different services within smart home environments. In contrast, the *Soft Remote Control* system [39] is integrated into the users' environment, which enables device-independent interaction between users and different home services. The system allows users to control devices by pointing at an object within the room and using pre-defined hand gestures to execute different functions [38]. Other smart support services for everyday activities include orientation and navigation services [39] or context-sensitive kitchen assistants [32].

III. Motivation and Goal

In many Ambient Assisted Living environments, large interactive screens are an integral part of the environment and are used to provide personalized information and context-adapted services throughout the users' home [40]. Most technical problems encountered in early prototype systems are solved by now and continuously falling retail prices make a widespread integration of interactive displays only a question of time. While tremendous efforts have been undertaken to overcome technical and economical barriers, very few considerations have been given to the perceived usefulness of ubiquitous screens from a user's perspective [41]. Individuals live in environments and expect technology to be adaptive and useful, however, what is judged as useful may change depending on the application domain and usage context [12]. For example, a study by Arning et al. [42] revealed that one and the same mobile device evokes different perceived benefits and drawbacks when used in a communication scenario compared to a medical monitoring scenario. Hence, the acceptance or rejection of a technical product is neither static nor independent from the specific context, in which the product is used. While the potential benefits of Ambient Assisted Living are undeniable, there is very limited knowledge about the acceptance of large screens for the different types of AAL services in home environments. So far, technical developments still disregard or underestimate humans' technology acceptance and individual usage motives and barriers. Smart home technology can only fully deploy its huge potential for graying societies, if acceptance issues of electronic applications are adequately considered and addressed.

IV. Method

The work presented in this paper was motivated by a lack of fundamental research in this area and aims at exploring the acceptance of large interactive screens for the most common types of AAL applications: (1) health services, (2) social services, and (3) convenience services for everyday activities.

A. Variables

As *independent variables* the impact of the usage context is examined (health services, communication services and convenience services). In addition, the impact of individual variables on acceptance is examined. In this context, a broad variety of factors were taken into consideration: age, gender, the users' sensitiveness to health issues, the need of regular medical care, the reported interest in technology, and the perceived ease when using common technical devices). *Dependent variables* were the acceptance of different usage contexts.

B. Questionnaire

In order to examine a wide range of participants and to adequately address the diversity of users, a combination of the questionnaire method and scenario technique was chosen.

The questionnaire was divided in three sections. The first part included demographic data. The second section addressed participants' technical experience, the usage frequency of common ICT devices and the perceived ease of using these devices. Then, participants were introduced into the field of AAL by presenting the following scenario:

"*Imagine that you live in a future house. In this house the rooms' walls represent huge displays, which may provide different information and electronic services, ranging from fun and gaming applications, over information and communication services to telemedical services. From a technical point of view, smart homes are basically feasible. Though only little knowledge exists about the acceptance of electronic services within private spaces and the perceived benefits and disadvantages, which have to be considered in order to harmonize technical developments and user requirements"*.

After this generic introduction, three different application contexts were given: (1) The first application area refers to social living of residents, in which the wall allows a virtual visit to friends and family or to talk to remote colleagues. (2) Within the second application, the wall delivers health services and represents an electronic health manager. (3) Within the third context, the wall was introduced to act as a personal assistant, which is responsible for everyday electronic activities (banking activities or electronic shopping). Participants were requested to envision the usage of these three different services and to state if they would accept technologies like these.

C. Evaluation Criteria

In order to examine adequate evaluation criteria, which actually meet cognitions of potential users, focus groups were carried out prior to this questionnaire study, in which different users discussed potentials and pitfalls of electronic services in home environments. In Table 1, items within the social communication domain are visualized.

TABLE I. ACCEPTANCE/EVALUATION CRITERIA FOR ELECTRONIC SERVICES FOR THE SOCIAL LIVING CONTEXT

Would you be generally willing to use intelligent walls for communication and social services?
Which requirements would such technology have to fulfill?
• I don't care who can look into my apartment from the "outside".
• It is important to me that I can see my communication partner.
• For me an audio connection with my communication partner is sufficient.
• I would agree if I could only be seen in predefined rooms.
• It is important to me to meet multiple persons simultaneously.
• It is important to me that the wall enables me to jointly experience things.
• I perceive such applications as an invasion into my private sphere.
• I think there are other ways to meet with friends.
• I think it is important that the exchange via the wall follows certain communication rules.
• I could imagine to be continuously connected with very close friends.
• It is important to me that each communication can be individually started and ended.

In Table 2, the items of the health scenario and in Table 3, the items for everyday electronic services are listed.

TABLE II. ACCEPTANCE/EVALUATION CRITERIA FOR SERVICES FOR THE ELECTRONCI HEALTH CONTEXT.

Would you be generally willing to use intelligent walls for health applications?
Which requirements would such technology have to fulfill?
• I don't care that my fitness coach / doctor can look into my apartment from the "outside".
• It is important to me that I can see my fitness coach / doctor.
• It is sufficient if I have an audio connection to my fitness coach / doctor.
• I would agree if I could only be seen in previously defined rooms.
• It would be important to me to meet multiple fellow sufferers simultaneously.
• I perceive such applications as an invasion into my private sphere.
• It is important to me that I have an extensive exchange with people, who have similar communication interests.
• No electronic device substitutes the direct contact with my fitness coach / doctor.
• I think it is important that the exchange via the wall follows certain communication rules.
• It is important to me that each communication can be individually started and ended.

TABLE III. ACCEPTANCE/EVALUATION CRITERIA FOR EVERDAY ELECTRONIC SERVICES

Would you be generally willing to use intelligent walls for electronic everyday services?
Which requirements would such technology have to fulfill?
• I don't care that my sales/service assistant can look into my apartment from the "outside".
• It is important to me that I can see my sales/service assistant.
• It is sufficient if I have an audio connection to sales assistants.
• I would agree if I could only be seen in predefined rooms.
• It is important to me to meet friends via the wall for a joint shopping tour.
• I perceive such applications as an invasion into my private sphere.
• It is important to me that I have an extensive exchange with people, who have similar communication interests.
• I think it is extremely helpful if I get electronic assistance for everyday activities via the wall.
• I think it is important that the exchange via the wall follows certain communication rules.
• It is important to me that each communication can be individually started and ended.

D. Participants

The data of N = 60 participants, aged between 14 and 60 years (M = 35.7; SD = 14.7) was analyzed. Regarding gender, the data of 30 males and 30 females were compared. In order to examine age effects, three age groups were formed: the first group (14 - 30 years) consists of 20 persons (M = 21.4; SD = 2.6; 36% women), the second age group (N = 20) consists of males (70%) and females (30 %) between 31 and 48 years (M = 32.6; SD = 5.3). The third age group (N = 20) is between 50-69 years (M = 53.2, SD = 8.4) with a proportion of 75% females and 25% males.

15 persons (25%) out of 60 respondents indicated to suffer from a chronic disease. Overall, all participants had a solid experience with common ICT and reported to be comparably high educated. Younger participants were either university students of various academic fields or persons being in vocational training. Other respondents were reached by advertisements in local newspapers.

V. RESULTS

Results were analyzed by (M)ANOVA procedures (differences between age groups and gender). The level of significance was set at 5%. First, the outcomes in the evaluation criteria across the three usage settings of the intelligent wall (social life, health management and everyday services) are compared regarding age and gender effects. Second, in order to understand to which extent individual factors predict the acceptance of the electronic services in the three usage contexts, correlation analyses were carried out.

A. General willingness to use the intelligent wall

First, respondents had to indicate if they would use the intelligent wall at home in the respective application domain.

For the *social services* setting, 28% of respondents decline the usage and 18.3% indicate to probably not use the electronic service. In contrast, 35% persons fully accept the electronic delivery of social services and at least 18.4% answer with "probably". Age, gender or respondents' health states did not impact the willingness to adopt this kind of electronic service.

Regarding the *health management setting*, also no differential effects of age, gender and health status were found. However, the health setting receives a more negative overall evaluation. 38.3% refuse to use the wall and 11.7 % indicate to probably not use the wall for health issues, in contrast to 21.7% and 28.3% of respondents who answered with "probably" or "yes".

Finally, respecting the usage of the intelligent wall for everyday services revealed a similar negative evaluation. Independently of individual variables, the majority of the sample (35%) declines to use the wall and 26.7% would "probably not" consider it. In contrast, 13.3% would "probably" use the wall, while 23.3% would definitively use it ("yes").

We also looked at intercorrelations between the willingness to use the intelligent wall across the different services and application fields. In fact, persons who would like to use social communication services, report also to be willing to use the medical health services ($r = .572$; $p < .000$) and to use the electronic services for everyday requirements ($r = .687$; $p < .000$). Apparently, it is a more general openness to use electronic services via smart walls and to a lesser extent the specific application domain that is crucial for acceptance and determines the basic willingness to use these services.

B. Correlation of individual factors and terms of use

In this section, we report on the correlations between individual factors and the users' requirements within the different setting. In order to understand if and which individual characteristics impact the acceptance evaluations, we report illustrations in which the individual factors are pictured in circles (e.g. Fig.1 for the social communication setting) on the one side and the single items in rectangles on the other. For a quick overview, it is then easy to see which of the user factors shows the most connections to the single items and therefore is a crucial variable influencing the acceptance outcomes.

The wall delivering social communication services: Starting with the first application domain, the social communication services (Fig. 1), there are factors that do not show any relations to the users' evaluations: *Age*, *gender*, the need for *regular medical care* as well as the perceived *ease of using* common technology do not play a role.

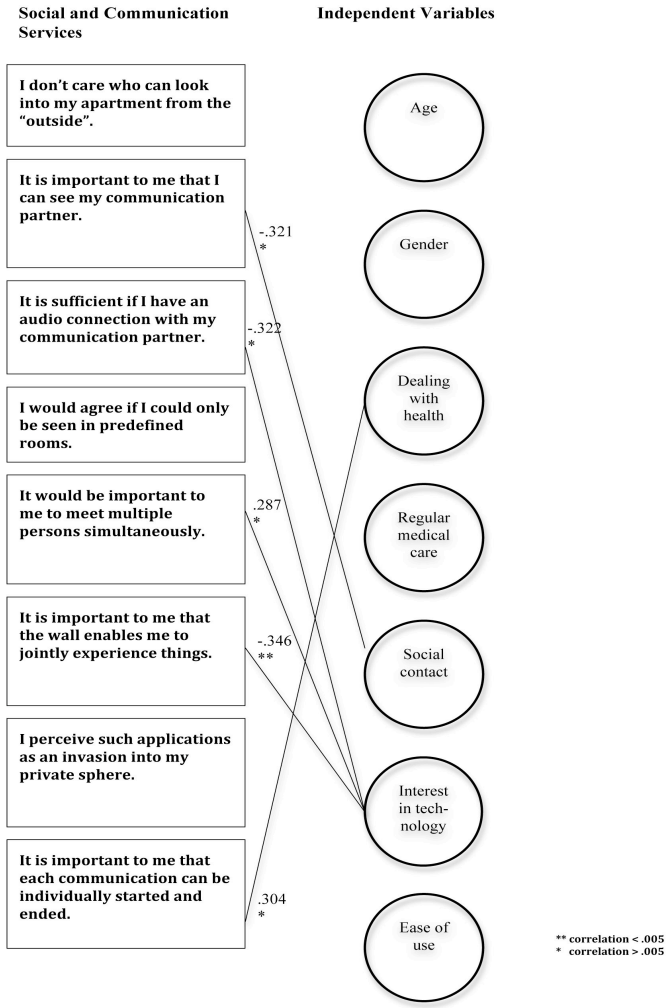

Figure 1. Correlations between individual factors and terms of use in the social communication scenario (N = 60)

In contrast there was a single user factor, the reported *interest in technology*, which is the most important variable. Persons with higher interest in technology are not satisfied with an audio connection with communication partners and would meet multiple persons simultaneously when using the intelligent wall, and attach lesser importance to jointly experience things when using the wall in comparison to persons with lower levels of interest in technology. For respondents, who indicate to sensitively *deal with health issues*

and who are health conscious it is quite important that each communication can be individually started and ended. Finally, people with a high frequency of social contacts, attach greater importance to seeing the communication partner on the wall compared to persons, who report to have fewer social contact.

The wall delivering health and medical services: In the second setting, users had to envision that they would need medical care and to evaluate, which conditions have to be fulfilled in order to accept the smart wall as a health manager. Again, there are user factors that do not play a role for the evaluation of the usefulness of the intelligent wall as a electronic health interface (Fig. 2): *gender*, the *sensitiveness to health* issues and the need of *regular medical care*. Astonishingly, the evaluation is not impacted by the health status of respondents and their awareness of maintaining a good health status. Also, the reported *ease of using* common technical devices does not impact the evaluation of the intelligent wall in the health and medical setting.

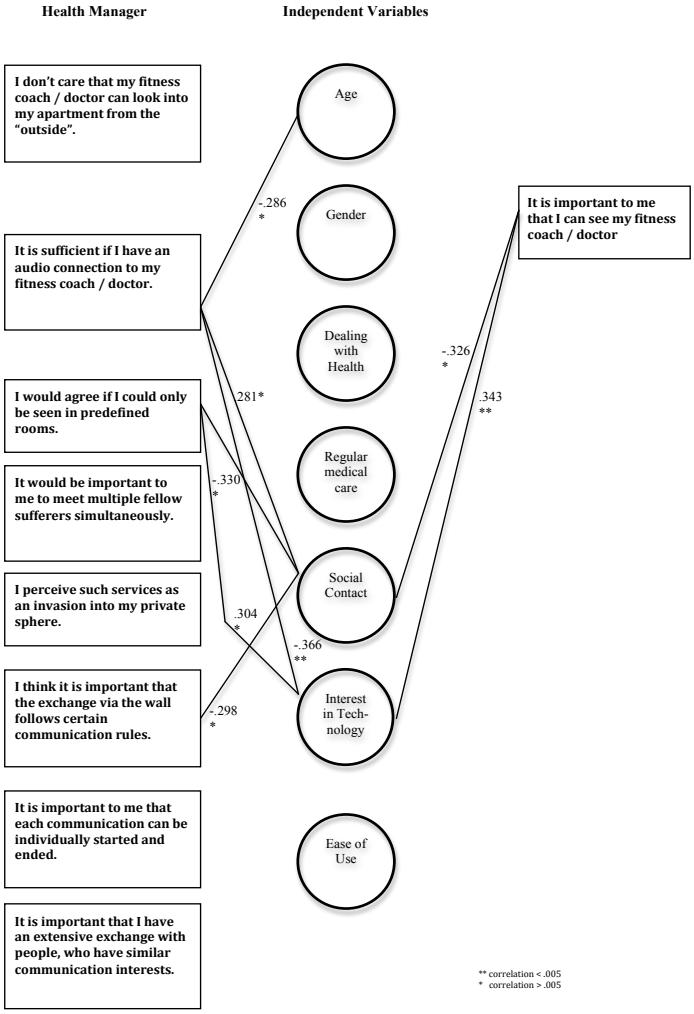

Figure 2. Correlations between individual factors and terms of use in the electronic health/medical scenario (N = 60)

The degree and the frequency to which persons foster *social contacts* is an important variable. People with a high frequency of social contacts do not find it sufficient to have only an audio connection and would like to see the doctor while communicating. Further, they would accept the service in predefined rooms and find it important that the communication via the wall follows certain communication rules.

In addition, the *interest in technology* reveals to be a prominent user factor. People with a high level of technical interest do not insist that they can see the doctor, that the communication is limited to predefined rules and that the communication with the doctor has to follow certain communication rules. Regarding age, there was only one significant correlation: The younger users are, the more they report to accept to have only an audio connection to the doctor. With increasing age this is not evaluated as being sufficient.

The wall delivering convenience services for everyday activities: Finally, in the third setting, in which electronic everyday activities were to be completed with the help of the smart wall, a different picture was found. In Fig. 3, correlation outcomes between the necessary terms of usage and individual factors are illustrated.

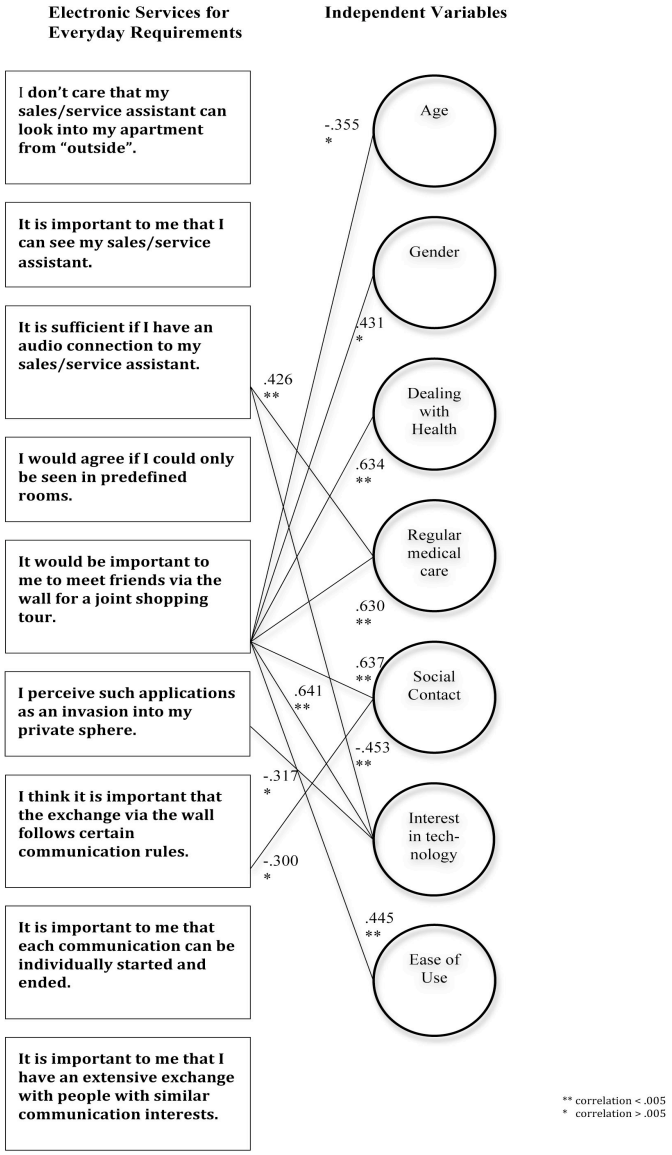

Figure 3. Correlations between individual factors and terms of use in convenience services for everyday activities (N = 60)

At first sight, it is noticeably that user factors do play a much larger role in this setting when compared to the previous application contexts: All of the user factors taken into consideration had an impact on the electronic service requirements that have to be fulfilled before people would be willing to use it. Among the 10 requirements that had to be evaluated, one seems to be of particular importance: Meeting friends via the smart wall for a shopping tour. The possibility to jointly undertake shopping tours is more important for men than for women and is the more important the younger respondents are, the higher the social contact level and the more pronounced the interest in technology is. Furthermore, joint shopping is more essential for persons, who rate the usage of common technology as easy. It is an interesting finding that people, who need medical care and attach great importance to health-related behaviors also prefer to undertake joint shopping tours.

VI. Discussion and Outlook for Future Research

In this research, we explored the willingness of respondents to accept electronic services in different application domains in home environments and the requirements, which should be fulfilled before users indicate to be willing to use these electronic services. As the usage setting for which electronic services might be applied could considerably impact the acceptance, this research was motivated by a lack of fundamental research in this field and aimed at exploring the acceptance of large interactive screens for the most common types of AAL applications: health services, social communication services, and convenience services for everyday activities.

In order to address the large diversity of potential end users, a broad variety of user factors were taken into account. Beyond age and gender, we explored the relation of health awareness, need for medical care, the frequency of social contacts, the interest in technology and the reported ease of using common information and communication technology.

Overall, it was found that the sample examined here showed a comparably low willingness to use smart walls for the electronic services under study. In contrast to studies dealing with the perceived usefulness of telemedical applications [43] [44], astonishingly, neither age nor gender did impact the evaluation of the different usage settings. This shows that the evaluation of the electronic services and application fields examined in this study reflect a rather universal phenomenon, which is not modulated by technical experience, age or gender. When focusing on single requirements that have to be fulfilled before users would be willing to use a service, the interest in technology and the level of social contacts are the user factors, which showed the highest relations to acceptance.

Regarding the question if the perceived usefulness of the given settings might be different depending on the application field, there was no clear picture. On the one hand, convenience services for everyday activities seemed to provoke the highest response. On the other hand, it was revealed that persons who would be willing to use one setting also confirm their willingness to use the services in other usage contexts. This shows that it is presumably a more general openness to use electronic services within smart homes and to a much lesser extent the specifics of the application domain that determines the acceptance of services.

The low perceived usefulness of electronic services within smart homes could, at first sight, lead to the conclusion that the usage of smart walls is not yet very welcomed by potential users and are therefore not evaluated as helpful electronic assistance, even though it is common knowledge that the consequences of the demographic change and the related shortcomings of caregivers make intelligent solutions in homecare necessary.

Nevertheless, there are some cautionary notes, which should be considered in this context from a methodological point of view. Using the scenario technique [45] in this study, respondents were encouraged to envision the respective usage scenario and to feel if and under which circumstances they would be willing to use intelligent walls. However, one could critically argue that it is questionable whether the evaluation of an envisioned usage provokes the same responses than a real home setting, in which respondents rely on usage experience. For example, in studies, e.g. [46], dealing with the exploration of the perceived usefulness of a AAL homecare technology, participants felt that seeing the real contact with the technology in action changed not only their evaluation regarding the usefulness of the application but also their impression of the technology to be used in the care of real patients [16]. Also, Acquisti et al. [47] as well as Cvrcek et al. [48] emphasize the disadvantage of abstract empirical settings, which may seduce respondents to overestimate fears and barriers and the sensitiveness to violations of privacy and intimacy by technology [48]. Thus, it is not clear whether the reluctance and the cautious attitude towards smart home technologies revealed in this study is not biased by the methodology used.

To examine how users communicate with smart technology in home environments, how they deal with invisible technology, and how information is to be delivered such that it meets the requirements of timeliness, data protection, dignity as well as medical demands, an experimental space is necessary, which enables to study patients “life at home”.

Traditional device development usually assumes that users are interacting with a single device in isolation. But of course, this does not match reality. User experience is embedded into a spatial context (e.g., homes), and this spatial and functional context defines the background against which the use of devices has to be constructed. Thus, technical devices are to be conceptualized within a shared spatial context, where technology supports users seamlessly through everyday objects (e.g., furniture), but also room components (e.g., floors or walls). These environments may be designed to take over different roles, functionalities and services (e.g., assistance and care).

Future studies will therefore have to validate the findings

in real settings, by using a living lab approach, in which potential users can get hands-on experience with different electronic services [18] [41].

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