Understanding Trust in Medical Technologies

Wiktoria Wilkowska and Martina Ziefle
Human-Computer Interaction Center, RWTH Aachen University, Campus Boulevard 57, Aachen, Germany

Keywords: Trust, Medical Technology, Ambient Assisted Living, User Diversity, Age, Gender.

Abstract: This paper aims to extend knowledge with respect to trust in health-related technology and deals with an exploration of this topic and the validation of the findings using multi-method research. The empirical approach aimed at the evaluation of the opinions and attitudes towards the importance of trust conditions (reliability, trustworthiness, operability and easing) and trust "mediators" (physician as a role model, scientific evidence, exchange with peers and hands-on experience), and assessed the relevance of different system features among different users. User factors such as age, gender and the perceived health condition were taken under consideration as representative indicators of the diversity among the (potential) users. Results showed a significant influence of age and gender on the examined trust indicators and underline the importance of considering the users' diversity in the research of trusted – and thus accepted – medical systems in home environments.

1 INTRODUCTION

Electronic health technology (eHealth) in the context of Ambient Assisted Living (AAL) represents one of the biggest shifts in healthcare today. Innovative advancements in digital technology allow healthcare organizations to change the way healthcare is delivered, and users to reframe their view on how they can maintain their health and well-being more independently. Currently, many institutions and stakeholders are making efforts to optimize and/or improve the infrastructure in this regard to ensure the widespread use of the common health-supporting technologies at home.

Therefore, health-related technological devices which monitor the relevant vital parameters and offer support to manage the well-being of people outside of traditional medical institutions have a great potential to rapidly become common tools to support health-care in people's homes. However, the success of the adoption of such ambient medical technologies largely depends on the extent to which users trust, and can rely on, the equipment. In addition, it is crucial to understand how people will trust in ambient medical technology systems while achieving and maintaining their privacy (Little et al., 2007). Especially in the field of medical technology, it is therefore important to adapt the devices to the special needs and – if possible – to wishes of the (potential) users which, naturally, requires a careful examination of the differences between the users.

1.1 The Phenomenon of Trust

Research with respect to the integration of information systems indicates that trust plays an important role in helping users to overcome perceptions of risk and uncertainty in the use and acceptance of new technologies (Li et al., 2008; Pavlou and Grefen, 2004). Despite the broad consensus that trust in technology is one of the most important factors in the technology saturated society (Lewis and Weigert, 1985; Falcone and Castelfranchi, 2001), the phenomenon of trust is anything but clear and consistent in the relevant literature. It does not only concern the different contexts of the computerized society (e.g., information and communication technologies, e-commerce, intelligent physical environments, virtual reality, etc.) but also people's trust in a secure digital infrastructure, sources of information, data, personal assistants, and processes and software.

Trust is not easily defined. The extensive amount of research regarding trust leads to a certain fuzziness of the definition of trust, resulting in some difficulties to clearly understand the term. The main reason for this is its multidisciplinary and multi-contextual nature. For instance, Boon and Holmes

Wilkowska, W. and Ziefle, M.
Understanding Trust in Medical Technologies.
In *Proceedings of the 4th International Conference on Information and Communication Technologies for Ageing Well and e-Health (ICT4AWE 2018)*, pages 62-73
ISBN: 978-989-758-299-8

(1991) defined it as "a state involving confident positive expectations about another's motives with respect to oneself in situations entailing risk" (p. 194). Within the field of e-commerce, trust is related to three perceptual factors that have an impact on online trust: perception of credibility, ease of use and risk (Corritore, 2003). Then again, Wang and Emurian (2005) identify four elements of online trust regarding interface design features, which relate to graphic, structure, content and social-cue design. The evidence that the design of an interface can significantly impact the perceived trustworthiness of a system also applies to mobile technologies (Siau and Shen, 2003). Thus, researchers often conceptualize trust according to the features of a particular context (Sillence et al., 2006).

Studies involved in the development of a framework for the construct of trust in the context of medical technology proved that the trust in medical technology empirically differs from the general trust in technology (Montague et al., 2009). The phenomenon of trust seems to be more indispensable when health-relevant aspects are technology-mediated (Wilkowska, 2015). The concept is multi-faceted and includes different factors which might be important for understanding how the acceptance and long-term adoption of health-enhancing technologies can be ensured; these factors concern, among others, personalization, motivation, expertise, familiarity, predictability, sensitivity, and the source of the information.

Because of the rising number of older people, and thus presumably those with rather frail health, patient's trust in medical technology may be an important factor of functionally working systems; especially since health care work systems move to a higher reliance on and use of medical technologies (Montague, 2010). As a fundamental attribute in the adoption of health-supporting technologies, trust refers to a variety of relationships: interpersonal trust (e.g., in the patient-physician communication), trust in the environment and in the infrastructure (Falcone and Castelfranchi, 2001), social trust (e.g., in a healthcare institution) and the trust in automation (Muir, 1994).

In the context of emerging AAL-environments, where technology is meant to assist people in their everyday life and support them in terms of their health (e.g., monitoring devices, measurement of vital parameters, sensors recording fall detection, etc.), trust is a particularly important phenomenon, which has been barely researched yet. Individuals are confronted with situations, in which they have to trust the medical devices that are incorporated in an ambient technology system and which, depending on how much their health impairments have them rely on this technology, become part of their life. In this context, trust is more likely to be a dynamic process, which might change depending on the users' characteristics (e.g., age, gender), current health conditions or the changing circumstances of their lives. Considering the differences between the (potential) users is, therefore, of utmost importance.

1.2 The Differences in the Users

For a long time, the scientific studies of information technology have perceived that individual differences exert a major force in determining its success (Zmud, 1979). Accordingly, a lot of scientific evidence shows that differences in socio-demographic characteristics, computer experience, cognitive abilities, and personality are significant factors in explaining both technology acceptance and user behaviour (e.g., Gefen and Straub, 1997; Rogers and Fisk, 2000; Ong and Lai, 2006; Wilkowska and Ziefle, 2009).

Especially age, as a factor of user diversity, plays an enormous role in the explanation of the variability in system acceptance and performance. Not only the users' belonging to a particular technology generation (e.g., Sackmann and Winkler, 2013) and the connected know-how, perceived self-efficacy and attitudes towards technology, but also the users' mental and physical state can decisively influence their trust in, and use of, a certain technology system. Therefore, the development of age-sensitive and age-appropriate interfaces is highly challenging because aging itself is a very complex and differential process. The same applies to the users' gender and the resulting differences with respect to technology perceptions and behaviours (e.g., Schumacher and Morahan-Martin, 2001; Broos, 2005; Gaul et al., 2010). Changes in health conditions or stressful life events can also have a strong impact on the perception of, and intention to use, assistive technology (e.g., Wilkowska, 2015).

Recent research dealing with the acceptance of technology in the context of health-supporting technologies in the domestic settings, increasingly considers different users and their different needs in the development and design process (e.g., Demiris et al., 2004; Klack et al., 2011; Wilkowska and Ziefle, 2011; Ziefle et al., 2016a). Since this technology is primarily intended for the elderly, disabled and/or people with a chronic disease, it must be taken into

account that their trust in such an assistive technology may largely differ from the trust of younger, healthy and carefree users.

1.3 Questions Addressed

Based on the described considerations, the present research examined the concept of trust contextually regarding the increasingly used medical technology in home environments. The approach was performed in two empirical steps: First, using a qualitative research method to explore the topic of trust in the upcoming context from scratch. For this, participants should discuss different trust aspects of the integration of the technology in the living environment (socio-technical system) and the trust in a system or institution which manages the health data (social trust), over the interpersonal trust (e.g., in the communication with the physician in charge) through to the perceived reliability and demands regarding technical device or system (technological trust). After that, the qualitative results were validated using quantitative method to ascertain the generalisability of the findings. Unlike in the previous research, special focus was thereby directed to the user diversity which was assumed to considerably influence the trust itself.

2 METHOD

The content described in this paper are part of a wider range of studies conducted to explore the users' perceptions and requirements regarding medical assistive technologies in home environments (see Wilkowska, 2015).

The concept of the described empirical studies uses a user-centred design approach, the main goal of which is to reveal how technical systems must be designed for, and adapted to, the individual concepts and mental models of the (potential) users.

In this study on the trust in, and the perception of privacy towards, electronic health technology, opinions regarding the characteristics that are perceived as necessary to the use of (and trust in) medical devices, as well as conditions for the use of such devices, were collected. For this purpose, a multi-method empirical approach was pursued which is described in more detail hereafter.

2.1 Multi-method Approach

Considering the user-centred design of the conducted qualitative and quantitative studies, special attention was paid to user diversity (e.g., user's age, gender, physical/health condition, etc.) and the dynamics of personal biographies (e.g., the onset of an illness). Therefore, some of these criteria were decisive for the composition of the focus groups which represented the first step of the empirical procedure.

2.1.1 Focus Groups

Focus groups were arranged to gather qualitative information about the designated topic. This method was chosen because group interactions may accentuate members' similarities and differences in a particular context and provide rich information about the range of perspectives, opinions, cognitive beliefs and experiences (Lambert and Loiselle, 2008). The idea was to initially explore the topic of trust and acceptance in the context of the use of different medical technology devices in a domestic setting. Therefore, a relevant part – next to the topic of privacy in the context of eHealth technology – were the discussions about the aspects which are relevant, or even indispensable, for a trustable and accepted (daily) use.

In three focus groups sessions (N=15), women (60%) and men of different ages (age range: 23-64 years) exchanged their views on the following questions: "In your opinion, which characteristics of a health-related technology which is used in a home environment are essential?" and "Which conditions would have to be fulfilled for you to use (and trust) a medical-support device which has to be used at home?". Considering the preceding discussions about the thematically related topics of 'trust' and 'privacy' when dealing with health-supporting equipment, and after the introduction of the related topics, like chronic diseases (e.g., cardio-vascular conditions, diabetes, etc.), the process of ageing and the need for care, participants presented their requirements, reservations and conditions of usage. The objective was to find out which basic characteristics of the devices are expected and which conditions are required by the (potential) users to trust and rely on the interaction with such devices, in order to increase their acceptance and the adoption in the long run. The resulting expected characteristics of health-supporting devices which are used in home environments are summarized in Table 1. In Table 2, the conditions for trusted usage are presented.

Methodologically, focus groups allow a deeper insight into the nature of such sensitive and, somehow, difficult-to-grasp topics. However, the restrictions of the method refer to a comparably

small sample size and personally coloured results which are unrepresentative. To scientifically ascertain the representativeness of the findings, the outcomes of the focus groups were taken as an empirical base for the subsequent construction of survey items to allow further quantitative data collection with a larger sample.

Table 1: Expectations for eHealth devices for domestic use.

Item description	Scale
1. Unconditional reliability 2. Ease of use 3. Low price 4. Seal of approval / test label 5. Attractive / fashionable design 6. Unobtrusiveness 7. Officially recognized manufacturer 8. Recommendation of the physician 9. Financial support of the health insurance for procurement, maintenance, etc. 10. State of the art 11. Strict access control to the health data (e.g., by fingerprint)	Six-point Likert scale ranging from 1 ('not at all important') to 6 ('very important')

2.1.2 Quantitative Survey

In the next step of the empirical approach a questionnaire was conducted to quantitatively validate the most interesting findings.

The questionnaire was divided in three parts: In the first part, the participants answered questions about their socio-demographic profiles (e.g., age, gender, professional background, health condition etc.). They also reported their experience with health-supporting devices in their daily lives. The second part focussed on privacy in the context of health-supporting technology in domestic environments, but will not be analysed or discussed further in the present paper. The last part of the survey collected data on the trust in eHealth technology. To do so, respondents had to work on the following questions: 1) features and characteristics expected/required for the devices, 2) trust-conditions that must be met for accepted usage, and 3) complementary statements, retrieved from the focus group discussions, about what else makes the medical technology at home trustworthy.

The participants were recruited through advertisements in local newspapers, social networks on the Internet and collaboration with targeted societal groups (e.g., retirement home). Some of the respondents were also reached through the authors' personal contacts. There was an online version and a paper-based version of the questionnaire (from the latter especially the older participants benefited). On average, it took 15-20 minutes to complete the questionnaire and the data collection lasted for about four weeks.

2.2 Research Approach

In accordance with the concept of user-centred design (e.g., Abras et al., 2014; Mao et al., 2005), the research variables focus on different characteristics and health biographies of the users on the one side, and on their expectations and requirements for trusted health-supporting equipment at home, on the other.

2.2.1 Independent Variables

Technology users do not only hugely differ in their socio-demographic characteristics, but also in their sensory and cognitive skills, physical and motoric capabilities, and their different requirements (e.g., those linked to aging) which complicate an easy-going interaction with modern technical solutions (Wilkowska, 2015).

To deepen the understanding of the diversity among the (potential) eHealth users, as well as of their different needs and requirements, it is crucial to consider different points of view regarding the trust in such a technology. In the present statistical analyses, three independent variables, which refer to the participants' diversity, will be considered:

- *Age* [young (≤44 years; 50%) vs. middle-aged and older (45 years and older; 50%)];
- *Gender* [women (46%) vs. men (54%)];
- Perception of the own *health condition* [good (44%) vs. moderate (46%) vs. poor (10%)].

2.2.2 Dependent Variables

The dependent variables refer to the perceived trust in the eHealth technologies which are used in people's home environments for health monitoring, prevention and rehabilitation.

First, the required *features and characteristics* for eHealth devices (see Table 1) are considered as dependent variables. After that, the *conditions of trust* regarding health-supporting technology in domestic settings are examined. The items were evaluated using a six-point Likert scale ranging from 1 ('strongly disagree') to 6 ('strongly agree'). For a better overview, thematically related aspects are merged into categories (see Table 2). Next to the device's reliability, three other main categories of

trust conditions were generated (the internal consistency of the particular categories is indicated between brackets):

- Trustworthiness (Cronbach's alpha α=.71; min=3, max=18);
- Operability (Cronbach's alpha α=.73; min=3, max=18;
- Easing of the burden of the disease (Cronbach's alpha α=.83; min=2, max=12).

Table 2: Formed trust categories of eHealth technology.

Category	Item description
	"I would trust the medical device if…
Reliability	…it would immediately provide feedback about incorrect information and asks me to repeat the measurement."
Trust-worthiness	…I would know that it comes from an approved and trustworthy manufacturer."
	…its reliability would be confirmed by a recognized testing institution."
	…I would rarely have to see the doctor thanks to the device."
Operability	…I would intuitively understand how to handle the device."
	…I would be able to count on customer service in case I experience difficulties."
	…it would allow me to take it anywhere to make measurements."
Easing	…it would be integrated in my daily life so that I feel relieved from my illness."
	…it would give me the feeling of independence despite my illness."

Moreover, four *additional statements* on what else makes the use of a health-supporting technology at home trustworthy were added as dependent variables. Likewise, participants expressed their level of agreement (6='strongly agree') or disapproval (1='strongly disagree') regarding the aspects presented in Table 3.

Table 3: Additional statements regarding trust in eHealth.

Item description	Short description
"If my doctor relies on medical technology, I trust it."	*doctor as a role model*
"I consider medical devices whose quality and functionality are confirmed by scientific studies to be trustworthy."	*scientific evidence*
"I consider medical equipment, which functionality I can try out for a while without paying, to be trustworthy."	*hands-on experience*
"My trust in medical devices would be greater if I could exchange with peers."	*exchange with peers*

2.3 Participants

The sample intended to cover different population groups including young, middle-aged and older people with different skills, professional backgrounds and levels of experience with technology.

This study collected and analysed the data of N=104 participants (ages ranged between 21-98 years). More than 40% of the respondents reported to suffer from chronic health conditions (e.g., cardiovascular diseases, diabetes mellitus, asthma). Overall, more than half of them reported experience with health-supporting devices in everyday life: the most participants used blood pressure meters (32%), followed by those who used blood sugar meters (10%) and 9% used heart rate monitors; a few (6%) also reported to use hearing aids and insulin pumps.

Different professions (including teachers, engineers, economists, psychologists and mechanics) and different educational levels were represented in the sample; there was a quite high average level of education though. The participation in the study was voluntary and respondents were not compensated for participating.

3 RESULTS

For the statistical examination of the independent variables' significant influence on trust, multiple analyses of variance (MANOVA) were executed and the significance of omnibus *F*-Tests was taken from Pillai values. For descriptive analyses, the means (*M*) and standard deviations (*SD*) are reported, and the parameter partial eta squared (η^2) was calculated for the effect sizes according to Cohen (1988). For the continuous trust variables, Pearson's product-moment correlations (*r*) were calculated. The level of statistical significance (*p*) was set at the conventional 5%.

3.1 Expected Features for eHealth

In the first step, the influence of independent variables on the expected trust characteristics is statistically examined. A multivariate analysis of variance revealed a significant omnibus effect of age

[$F(11,76)=2.1$, $p=0.033$; $\eta^2=.23$] and gender [$F(11,76)=2.6$, $p=0.007$; $\eta^2=.27$].

The effects of age on the between-subject level resulted for the following characteristics: ease of use [$F(1,98)=7.6$, $p=0.007$; $\eta^2=.08$], low price [$F(1,98)=5.9$, $p=0.017$; $\eta^2=.06$], officially recognized manufacturer [$F(1,98)=7.3$, $p=0.008$; $\eta^2=.08$] and the state of the art [$F(1,98)=6.9$, $p=0.01$; $\eta^2=.07$]. The resulting means are depicted in Figure 1. It is evident that the middle-aged and older participants expect significantly higher standards for medical equipment in domestic settings than the young participants.

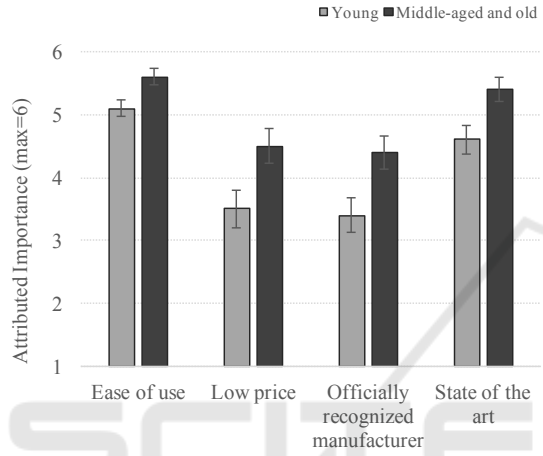

Figure 1: Effect of age on expectations regarding eHealth technology in home environments.

Considering the impact of gender the on expectations, the particular effects on the between-subject level result for unconditional reliability [$F(1,98)=4.6$, $p=0.035$; $\eta^2=.05$], seal of approval [$F(1,98)=7.7$, $p=0.007$; $\eta^2=.08$], ease of use [$F(1,98)=20.1$, $p\leq0.001$; $\eta^2=.19$] and recommendation of physician [$F(1,98)=5.6$, $p=0.021$; $\eta^2=.06$]. Descriptive data (Figure 2) demonstrate that women have higher expectations regarding health-supporting devices than men. According to the effect sizes, the impact of gender is especially meaningful for the ease of use of the medical technology.

3.2 Trust Conditions for eHealth

In the next step, the independent variables' influence on the usage conditions of health-supporting technologies in domestic settings were examined.

Analyses of variance revealed a significant main effect of gender on the condition of flawless operability of the digital medical technology in an AAL environment [$F(1,101)=4.2$, $p=0.043$; $\eta^2=.04$]. The influence of gender on the trust condition of operability is evident in Figure 3 (left).

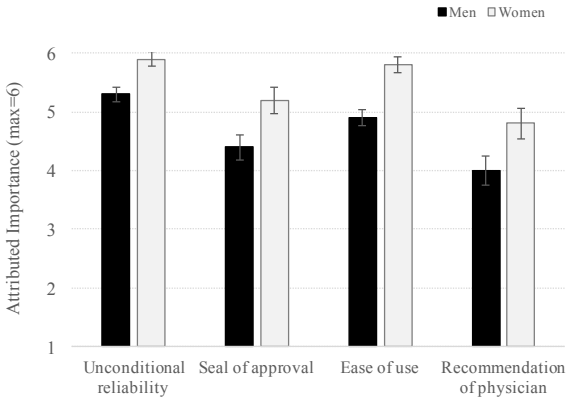

Figure 2: Effect of gender on expectations regarding eHealth technology in home environments.

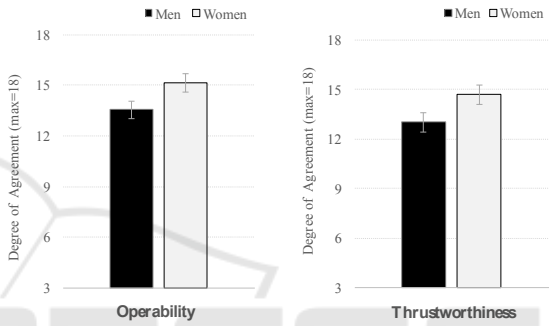

Figure 3: Main effect of gender on the conditions of operability (left) and trustworthiness (right) when using eHealth technology in home environments.

A similar pattern is noticeable regarding the conditions that form the trustworthiness [$F(1,100)=4.4$, $p=0.039$; partial $\eta^2=.05$]. The mean values are depicted on the right in Figure 3. Even when, according to the rather small effect sizes, the impact of gender is minor in both cases, the results indicate that women demand more stringent conditions for medical equipment than men.

In addition, the univariate ANOVA revealed moderate interacting effects of age and gender [$F(1,100)=8.7$, $p=0.004$; partial $\eta^2=.09$], as well as of gender and perceived health conditions [$F(2,100)=4.4$, $p=0.014$; partial $\eta^2=.09$], on the trustworthiness in health-supporting technology. Especially in the younger age group, men ($M=11.1$, $SD=0.8$) and women ($M=15.1$, $SD=0.8$) differ significantly, whereby women demand higher standards of trustworthiness in this context. As opposed to this, the differences in the group of middle-aged and older participants are not so evident between women ($M=14.3$, $SD=0.8$) and men ($M=15$, $SD=0.7$). The interaction is presented on the left in Figure 4. Moreover, visible at the right side of

Figure 4, the additional influence of health condition especially splits the opinions of those who report bad health: Whereas women require very high standards of trustworthiness (*M*=16, *SD*=1.5), men with poor health do not pay as much attention to this condition (*M*=10.1, *SD*=1.3). On the contrary, in the groups of good and moderate health both genders do not significantly differ in their opinions, both reaching high means for the condition of trustworthiness.

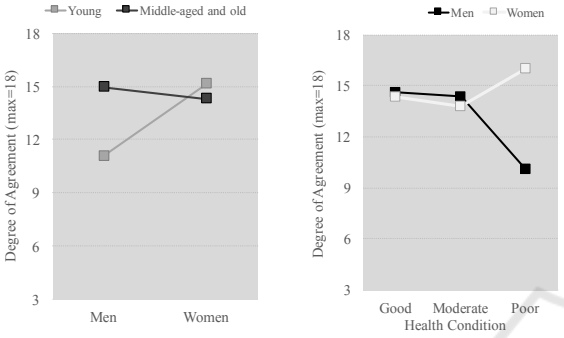

Figure 4: Interaction effects on the conditions of trustworthiness: age and gender (left), gender and health condition (right).

Furthermore, the statistical analyses of the trust conditions of reliability and of the easing of the burden of the disease, yielded no significant influences of age, gender or health condition. According to this, independent from the user diversity, all participants wished for highly reliable medical equipment which serves the purpose of exoneration.

3.3 Additional Aspects of Trust for eHealth

To complete the analyses related to trust in the context of health-supporting technologies at home, additional aspects which resulted from the aforementioned group discussions (see Table 3) were taken under consideration. The technique of three-way analysis of variance was chosen for the statistical evaluation.

Considering the aspect *'doctor as a role model'* as relevant for the trust in medical devices, an ANOVA with the factors age, gender and health condition revealed a significant effect of the participants' age [$F(1,102)=4.1$, $p=0.046$; $\eta^2=.04$]. Figure 5 shows the differences between the average values reached for both age groups. Even if the differences in the perceptions are small, the outcome shows that the middle-aged and older (*M*=3.6, *SD*=1.5) confide in the opinion of the doctor, who relies on the technology, more than young people (*M*=4.2, *SD*=1.5).

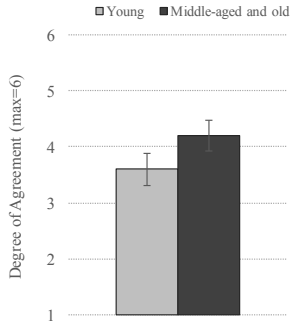

Figure 5: Main effect of age on the trust aspect 'doctor as a role model' for using eHealth technology at home.

In addition, for the aspect of *'scientific evidence'* the analysis of variance showed a moderate and strong influence of the user factors: (1) main effect of age [$F(1,101)=6.1$, $p=0.015$; $\eta^2=.06$]; (2) main effect of gender [$F(1,101)=4.5$, $p=0.036$; $\eta^2=.05$]; and (3) an interacting effect of gender and health condition [$F(1,101)=6.1$, $p=0.003$; $\eta^2=.12$]. The descriptive data for both main effects are depicted in Figure 6. The moderate effect of age (on the left side of the graph) shows that middle-aged and older people (*M*=4.9, *SD*=1.2) perceive medical devices whose quality and functionality is confirmed by scientific studies as more trustworthy than the younger participants (*M*=4.1, *SD*=1.4). Regarding the influence of gender (on the right in Figure 6), women's average values (*M*=4.9, *SD*=1.2) exceed those of men (*M*=4.1, *SD*=1.5), meaning that women's trust in medical equipment at home is slightly more shaped by scientific studies.

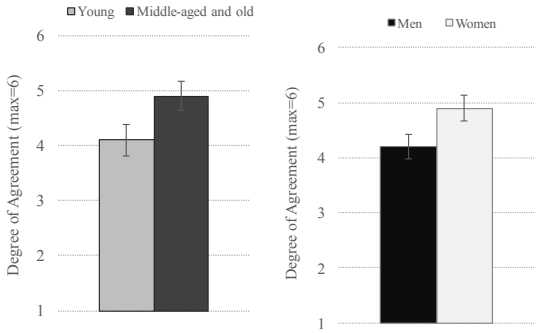

Figure 6: Main effect of age (left) and gender (right) on the trust aspect 'scientific evidence' for using eHealth technology at home.

Next to the influence of age and gender, an interacting effect of gender and the perceived health condition resulted for the aspect of 'scientific evidence'; Figure 7 depicts the means of the particular groups. Interestingly, for both genders the biggest differences in this regard result for those, who report poor health conditions, whereby women with poor health (*M*=5.7, *SD*=0.5) attach significantly higher importance to scientific evidence than men (*M*=3, *SD*=2) with the same health status.

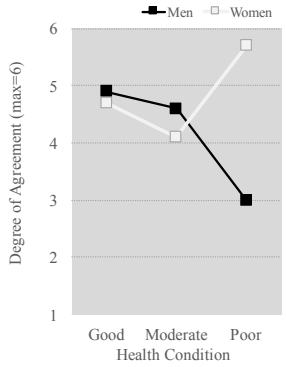

Figure 7: Interacting effect of gender and health condition on the trust aspect 'scientific evidence' for using eHealth technology at home.

Finally, a significant interaction effect of gender and health condition results for the trust aspect of '*exchange with peers*' [$F(2,102)=4.3$, $p=0.016$; $\eta^2=.09$]. The pattern is similar to the previous analysis: Compared to people with good and moderate health conditions in both genders, the opinions change for men and women with poor health conditions. Thereby, women (*M*=5, *SD*=0.8) consider it to be more important to exchange their opinions with peers than men (*M*=2.9, *SD*=1.6). The mean differences are showed in Figure 8.

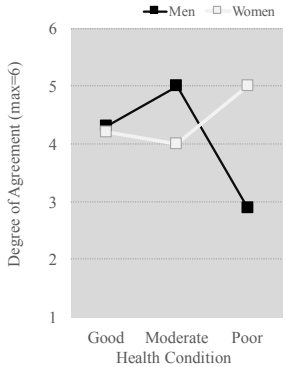

Figure 8: Interacting effect of gender and health condition on the trust aspect 'exchange with peers' for using eHealth technology at home.

For the aspect of '*hands-on experience'* the results are neither age-, gender-, nor health status-specific.

3.4 Special Case of Trust – the Reliability

In the final step of the statistical analyses, the interrelations between the researched trust variables and their association with the perceived usefulness – as a correlate of acceptance – of health-supporting technologies in home environments are presented.

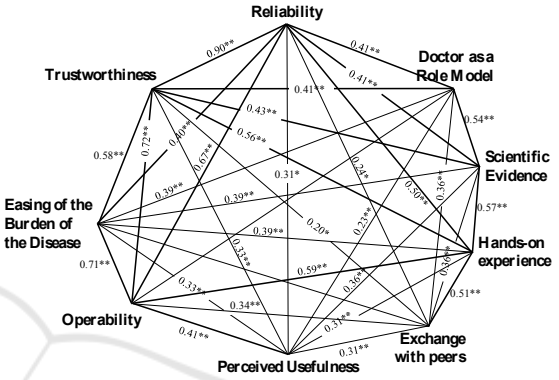

Figure 9: Interrelations of the research variables with the perceived usefulness.

As the previous analyses showed, the condition of reliability was not influenced significantly by the independent variables (i.e., age, gender and health condition). However, the results of the correlation analysis showed strong and moderate associations with the other trust factors mostly ranging from r=.40 (e.g., for the easing of the burden of the disease), to r=.67 (for operability), to r=.90 (for trustworthiness).

In the correlation analysis we additionally included the variable 'perceived usefulness' of health-related technologies to see how this acceptance indicator is connected to the trust variables elaborated in the presented studies. The results are astonishing, showing rather weak coefficients oscillating around r=.3 (e.g., with trustworthiness, reliability, scientific evidence). These findings suggest that trust in medical technology does not mean that people accept it, but – in accordance with relevant literature in this context – additional components are necessary for a high user acceptance.

4 DISCUSSION

In the present research, we focused on understanding the trust in and trustworthiness of medical technology which is increasingly used in home environments. However, this topic is part of a broader subject matter, regarding the acceptance of medical technology. Facing the demographic change and the increasing prevalence of medical technology integrated into people's lives and private spheres it is of utmost importance that users really do accept these technologies. However, acceptance is a truly complex issue, which – especially in this sensitive context – might not be easily described by the traditional factors of technology acceptance (Davis et al., 1989; Venkatesh, 2000). Plenty of usage motives as well as usage barriers in the context of medical technology are rather prevailing. In addition, the motives and barriers heavily depend on the situational context (e.g., when the medical technology is life-saving with no usage alternatives), the health status of the users (i.e., how severe is the disease for which the medical technology is used), and the personality of the user, including risk taking behaviour, coping strategies, technical self-confidence, media competence, etc. Moreover, as outlined before, it has been shown that demographic variables such as age, gender and education also considerably impact the extent to which people are willing to adopt and use medical technology.

Recent research uncovered the trust in, and trustworthiness of, medical devices as major facets of the acceptance of technology in the area of medical technology. On the one hand, this is obvious as the medical technology relates to sensitive and fragile health constitutions which rely on a high trust of users (Montague et al., 2009; Ziefle et al., 2011). On the other hand, especially for older and experienced people, one could assume that seniors might be less sensitive in terms of acceptance of technology, since they typically have no choice but to use it. Still, the nature of the perception of the trust in the area of medical technology and the question on which requirements and usage conditions might contribute to the perceived trust and trustworthiness, is underdeveloped so far.

In the presented empirical studies, users of different ages, of both genders and with different health conditions shared their opinions and attitudes towards the importance of trust "markers" (reliability, trustworthiness, operability and easing) and trust "mediators" (doctor as a role model, scientific evidence, exchange with peers and hands-on experience) and assessed the relevance of different system features. Overall, the studies disclosed findings, which turned out to be insensitive to user diversity as well as findings in which user profiles played a significant role. Regarding the differences between the genders, women attached a higher value to the ease of using medical technology in contrast to men. Moreover, women's trust in medical technology at home relies much more on scientific evidence, thus women shape their trust in line with the validation by science. When it comes to the impact of age, it was found that middle-aged and older participants significantly expect higher standards for medical equipment than younger users. In addition, middle-aged and older people confide in the opinion of the doctor, who relies on the technology, to a higher extent than younger people. An interesting finding referred to the fact that especially women with a poor health status report to rely on the exchange with peers, while in the opinion of men the peer-exchange is not that important for trustworthiness. The findings for the trust conditions of reliability and the easing of the burden of the disease yielded no significant influences of age, gender or health status. Apparently, there are deeply engrained attitudes that are not formed by the diversity of biographies and the change of values over the life-span.

On a higher level, the presented outcomes corroborate that user diversity, especially ageing and frailness, should be a benchmark for the development of medical technology. Technical design, especially in the field of medical technology field, should be aligned with the needs of the respective end users. This does not only include an understanding of the functional requirements of medical technologies, but also the reframing of traditional acceptance and usability benchmarks (mostly concentrating on ease of use and usefulness). In line with this, the perspective should be broadened by including intimacy and trust cognitions as a dictum for the design of a socially responsible medical technology.

Of course, the empirical approach also has some limitations which should be considered. The perception of trust is a highly complex topic, and the dimensions and facets which have been included in our empirical approach are only a quite arbitrary selection of attributes. It is obvious that there are many more aspects which require a closer analysis in future work.

Another limitation regards the impact of demographic variables on the perception of trust. Strictly speaking, one could argue that we only

superficially analysed the impact of the demographic variables on the perception of trust and trustworthiness in the area of medical technology. Even though the results provide interesting insights, age, gender and health condition are quite rough categories that need a closer look. Characteristically, the user factors age and gender are carriers for other factors, like social and societal attitudes, life experience, domain knowledge, skills and expertise, and general wisdom (Ziefle and Schaar, 2011) which, likewise, might be promising candidates which shape the trust in the health-supporting technology. Moreover, age is also connected to different values on and perspectives of culturally and societally anchored aging concepts. The moment users *feel* old, and the moment they *are* old might largely differ, depending on individual perspectives, but also on cultural and economic dimensions (Thiede, 2005; Hallenbeck, 2001).

Another limiting factor is the comparably small sample size. Even though the sample size might be methodologically and statistically appropriate for the carried-out analyses, it is still clear that trust and trustworthiness are inevitably intermingled with lifelong-learning and the understanding of broader user groups and cultural diversity. Future studies should therefore concentrate on more aspects of trust, using a larger sample size and addressing the understanding of trust in an intercultural setting.

Last but not least, we should also be aware that trust in medical technology and care has a policy component (Mechanic, 1998). In this context, it should be examined if the perceptions of trust and trustworthiness also include the competence of the medical treatments and the education of medical professionals, the individuals' confidence in the national or international efforts for ethical human care, and the diversity-fair treatment of patients at an older age (Wilkowska et al., 2018).

5 RESEARCH DIRECTIONS

The mentioned limitations are necessary to outline some research directions regarding the field of trust in health-supporting technologies in home environments.

Decidedly, patients' trust is an inevitable component of the future development of medical innovations that are increasingly implemented in domestic settings. Health and disease are inherent parts of humankind, which directly affect people's well-being, personal identity formation and life-span development. Therefore, any technology that seeks to be supportive for medical treatment and care needs to consider highly sensitive social issues, regarding both, physical and mental conditions.

In many cultures being old and ill is perceived as a stigma (Ziefle and Schaar, 2011) and is directly related to ageism—the negative societal framing of age and aging which is difficult to accept. Moreover, the combination of old age and chronic disease is closely related to end-of-life emotions, which are personality issues the patients are highly sensitive to; however, these also depend on different coping strategies, framed by societal and cultural values (Hamel et al., 2017).

In times of big data and the emerging relevance of the transportation and storage of medical/health data, electronic services and medical technology evolve to an enormous marketing good which contributes to the gain of knowledge on the one, and marketing success on the other, hand (Vervier et al., 2017; van Heek et al., 2018). The decision to share private medical data is therefore a delicate question for patients who need to weigh up between sharing their health-related data (and thereby support the societal medical gain of knowledge) and hiding their personal data and thus preserving their privacy and personal identity (Calero Valdez and Ziefle, under revision; Ziefle et al., 2016b).

Against this background, the present study is naturally only one drop in the ocean: Digital medicine and electronic technologies which are increasingly supporting people in domestic settings should perpetuate research on trust, privacy, disease management and aging and could include the following important research topics:

1) *Understanding the different perspectives of stakeholders*. This topic regards consideration of the entire caring situation, and the different people and roles as an integral part of it. So far, research regarding the trust in medical technology mostly considers the perspective of patients (e.g., Montague et al., 2009; Wilkowska and Ziefle, 2011, Wilkowska, 2015). However, the perspective of the caring personnel, be it of the family or the professionals, also represents an important point of view which needs to be integrated in the concept of trust towards medical technology and treatment.

2) *Understanding the impact and course of disease*. The openness to trust and accept medical technology necessarily depends on the health status. In addition, it might be essential to consider different types of disease and etiopathologies. Especially patients who suffer from chronic and serious diseases need to cope with the severity of the illness, the frailness and the end-of-life cognitions in a much

deeper and complex manner than patients with a temporary need for medical technology.

3) *Understanding age and aging.* Over time, cultures form individual and societal values of aging. These values change in line with economic, political and societal changes. Therefore, trust in a technology that supports caring naturally depends on the societal framing of the value of aging and the consideration of life-span developments. A recent study (Hamel et al., 2017) showed that acceptance patterns of, and trust in, medical care depend on the culture and the country, the different trade-offs between societally acknowledged caring mission of the very old, as well as the aspect of their life-end decisions (Bowling et al., 2002).

4) *Personality of patients.* Trust in the medical technology does not only depend on the caring context, the nature of the disease and the patients' age. The ability to trust is also associated with the personality and the available coping mechanisms of the concerned person. This part of the research agenda therefore addresses the patient's personality profiles towards trust and their openness for technical innovations. Particularly, it should be worked out whether these personal profiles are quite stable over the life course, or, are rather changing with age (Knowles et al., 2017).

ACKNOWLEDGEMENTS

The authors thank all participants for their patience and openness to share opinions on trust in medical technology. This work has been funded by Excellence Initiative of Germany's Federal Ministry of Education and Research and the German Research Foundation.

REFERENCES

Abdul-Rahman, A., 2005. A framework for decentralised trust reasoning. PhD thesis, University College London, London.

Abras, C., Maloney-Krichmar, D., Preece, J., 2004. User-centered design. Bainbridge, W. Encyclopedia of Human-Computer Interaction. *Thousand Oaks: Sage Publications*, 37(4), 445-456.

Boon, S. D., Holmes, J. G., 1991. *Cooperation and prosocial behavior*, Cambridge University Press. Cambridge, 1st edition.

Bowling, A., Banister, D., Sutton, S., Evans, O., Windsor, J., 2002. A multidimensional model of the quality of life in older age. *Aging Ment. Heal*. 6(4), 355–371.

Broos, A., 2005. Gender and information and communication technologies (ICT) anxiety: Male self-assurance and female hesitation. *Cyber Psychology & Behavior*, 8(1), 21–31.

Calero Valdez, A., Ziefle, M., under revision. The Users' Perspective on Privacy Trade-offs in Health Recommender Systems. *International Journal of Human-Computer Studies*.

Cohen, J., 1988. Statistical power analysis for the behavioral sciences. Hillsdale, NJ: Erlbaum.

Corritore, C.L., Kracher, B., Wiedenbeck, S., 2003. On-line trust: concepts, evolving themes, a model. *International Journal of Human-Computer Studies*, 58(6), 737–758.

Davis, F.D., Bagozzi, R.P., Warshaw, P.R., 1989. User acceptance of computer technology: a comparison of two theoretical models. *Management science*, 35(8), 982–1003.

Demiris, G., Rantz, M.J., Aud, M.A., Marek, K.D., Tyrer, H.W., Skubic, M., Hussam, A.A., 2004. Older adults' attitudes towards and perceptions of 'smart home' technologies: a pilot study. *Medical informatics and the Internet in medicine*, 29(2), 87-94.

Falcone, R., Castelfranchi, C., 2001. The Socio-cognitive Dynamics of Trust: Does Trust Create Trust? *Trust in Cyber-societies*, 2246, 55–72.

Gaul, S., Wilkowska, W., Ziefle, M., 2010. Accounting for user diversity in the acceptance of medical assistive technologies. In *Proceedings of the 3rd International ICST Conference on Electronic Healthcare for the 21st Century*, 175–173.

Gefen, D., Straub, D.W., 1997. Gender differences in the perception and use of e-mail: An extension to the technology acceptance model. *MIS quarterly*, 21(4), 389–400.

Hallenbeck, J.L., 2001. Intercultural differences and communication at the end of life. *Primary Care: Clinics in Office Practice*, 28(2), 401-413.

Hamel, L., Wu, B., Brodie, M., 2017. Views and experiences with end-of-life medical care in the US [Internet]. Kaiser Family Foundation.

Harrison, A. W., Rainer Jr., R. K., 1992. The influence of individual differences on skill in end-user computing. *Journal of Management Information Systems*, 9(1), 93–112.

Klack, L., Schmitz-Rode, T., Wilkowska, W., Kasugai, K., Heidrich, F., Ziefle, M., 2011. Integrated home monitoring and compliance optimization for patients with mechanical circulatory support devices. *Annals of biomedical engineering*, 39(12), 2911-2921.

Knowles, S.R., Tribbick, D., Connell, W.R., Castle, D., Salzberg, M., Kamm, M.A., 2017. Exploration of health status, illness perceptions, coping strategies, psychological morbidity, and quality of life in individuals with fecal ostomies. *Journal of Wound Ostomy & Continence Nursing*, 44(1), 69-73.

Lambert, S.D., Loiselle, C.G., 2008. Combining individual interviews and focus groups to enhance data richness. *Journal of Advanced Nursing*, 62(2), 228–237.

Lewis, J.D., Weigert, A., 1985. Trust as a social reality. *Social Forces*, 63(4), 967-985.

Li, X., Hess, T.J., Valacich, J.S., 2008. Why do we trust new technology? A study of initial trust formation with organizational information systems. *The Journal of Strategic Information Systems*, 17(1), 39-71.

Little, L., Marsh, S., Briggs, P., 2007. Trust and privacy permissions for an ambient world. In *Trust in e-services: Technologies, practices and challenges*, pp. 259-292. IGI Global.

Mao, J.Y., Vredenburg, K., Smith, P.W., Carey, T., 2005. The state of user-centered design practice. *Communications of the ACM*, 48(3), 105-109.

Mechanic, D., 1998. The functions and limitations of trust in the provision of medical care. *Journal of Health Politics, Policy and Law*, 23(4), 661-686.

Montague, E.N., Kleiner, B.M., Winchester, W.W., 2009. Empirically understanding trust in medical technology. *International Journal of Industrial Ergonomics*, 39(4), 628-634.

Montague, E.N., 2010. Validation of a trust in medical technology instrument. *Applied ergonomics*, 41(6), 812-821.

Muir, B., 1994. Trust in automation: Part 1. Theoretical issues in the study and human intervention in automated systems. *Ergonomics*, 37, 1905–1923.

Ong, C.-S, Lai, J.-Y., 2006. Gender differences in perceptions and relation- ships among dominants of e-learning acceptance. *Computers in Human Behavior*, 22(5), 816–829.

Pavlou, P.A., Gefen, D., 2004. Building effective online marketplaces with institution-based trust. *Information systems research*, 15(1), 37-59.

Rogers, W.A., Fisk, A.D., 2000. *Human factors, applied cognition, and aging*. Lawrence Erlbaum Associates Publishers.

Sackmann, R., Winkler, O., 2013. Technology generations revisited: The internet generation. *Gerontechnology*, 11(4), 493–503.

Schumacher, P., Morahan-Martin, J., 2001. Gender, internet and computer attitudes and experiences. *Computers in human behavior*, 17(1), 95–110.

Siau, K., Shen, Z., 2003. Building customer trust in mobile commerce. Communications of the ACM, 46(4), 91–94.

Sillence, E., Briggs, P., Harris, P., Fishwick, L., 2006. A framework for understanding trust factors in web-based health advice. International Journal of Human-Computer Studies, 64(8), 697-713.

Thiede, M., 2005. Information and access to health care: is there a role for trust*? Social science & medicine*, 61(7), 1452-1462.

van Heek, J., Himmel, S., Ziefle, M., 2018. Caregivers' Perspectives on Ambient Assisted Living Technologies in Professional Care Contexts. *4th International Conference on Information and Communication Technologies for Ageing Well and e-Health* (ICT4AWE 2018). SCITEPRESS.

Venkatesh, V., 2000. Determinants of perceived ease of use: Integrating control, intrinsic motivation, and emotion into the technology acceptance model. *Information systems research*, 11(4), 342–365.

Vervier, L., Zeissig, E.-M., Lidynia, C., Ziefle, M., 2017. Perceptions of Digital Footprints and the Value of Privacy. In *Proceedings of the International Conference on Internet of Things and Big Data (IoTBD 2017),* pp. 80-91. SCITEPRESS.

Wang, Y.D., Emurain, H.H., 2005. An overview of online trust: Concepts, elements and implications. *Computers in Human Behavior*, 21, 105-125.

Wilkowska, W., Ziefle, M., 2009. Which factors form older adults' acceptance of mobile information and communication technologies? *HCI and Usability for e-Inclusion*, 81-10, Springer.

Wilkowska, W., Ziefle, M., 2011. User Diversity as a Challenge for the Integration of Medical Technology into Future Smart Home Environments. In *Human-Centered Design of E-Health Technologies*, Hershey PA, 95-126.

Wilkowska, W., 2015. *Acceptance of eHealth Technology in Home Environments: Advanced Studies on User Diversity in Ambient Assisted Living*. Apprimus, Aachen.

Wilkowska, W., Brauner, P., Ziefle, M., 2018. Rethinking Technology Development for Older Adults. A responsible research and innovation duty. In *Aging, Technology, and Health*. Elsevier North Holland.

Ziefle, M., Schaar, A.K., 2011. Gender differences in acceptance and attitudes towards an invasive medical stent. *Electronic Journal of Health Informatics*, 6(2), e13.

Ziefle, M., Röcker, C., Holzinger, A., 2011. Medical technology in smart homes: exploring the user's perspective on privacy, intimacy and trust. In *Computer Software and Applications Conference Workshops (COMPSACW),* IEEE 35th Annual, pp. 410-415.

Ziefle, M., Brauner, P., van Heek, J., 2016a. Intentions to Use Smart Textiles in AAL Home Environments: Comparing Younger and Older Adults. In *International Conference on Human Aspects of IT for the Aged Population*, Springer International Publishing.

Ziefle, M., Halbey, J., Kowalewski, S., 2016b. Users' willingness to share data in the Internet: Perceived benefits and caveats. In *Proceedings of the International Conference on Internet of Things and Big Data (IoTBD 2016)*, pp. 255-265. SCITEPRESS.

Zmud, R.W., 1979. Individual differences and MIS success: A review of the empirical literature. Management Science, 25(10), 966–979.