Aging, Technology and Health

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ACADEMIC PRESS

An imprint of Elsevier

Academic Press is an imprint of Elsevier
125 London Wall, London EC2Y 5AS, United Kingdom
525 B Street, Suite 1800, San Diego, CA 92101-4495, United States
50 Hampshire Street, 5th Floor, Cambridge, MA 02139, United States
The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, United Kingdom

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Library of Congress Cataloging-in-Publication Data
A catalog record for this book is available from the Library of Congress

ISBN: 978-0-12-811272-4

For Information on all Academic Press publications
visit our website at https://www.elsevier.com/books-and-journals

Publisher: Nikki Levy
Acquisition Editor: Emily Ekle
Editorial Project Manager: Barbara Makinster
Production Project Manager: Kiruthika Govindaraju
Cover Designer: Limbert Matthew

Typeset by MPS Limited, Chennai, India

Rethinking technology development for older adults: A responsible research and innovation duty

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Starting point: Challenges for aging societies

Motivation

One of the largest and most powerful trends of our time is the global demographic shift resulting from changes in the population structures of many nations (Bloom, Canning, & Fink, 2010). Thereby, globally the population aged 60 years and over is growing at the fastest pace (United Nations, 2009). Rapid population aging and the development of the main drivers of the demographic change (i.e., increased life expectancy, birthrate decline, and migration) trigger complex social, political, and socioeconomic consequences, with which many nations already find themselves confronted.

Such consequences have become noticeable in Germany and are in line with many other Western societies: Public sector, which is especially affected by the demographic development, refers in particular to the statutory social insurance schemes, where, there is a strong link between service provision and age (Arnds & Bonin, 2002). Thus, financing of social insurance systems is strained and policy-makers face difficult decisions about changes to the benefit structures and taxes to support the so-called graying society. In addition, it is uncertain how economies will fare due to the demographic transition and how policies will affect the global flows of labor and capital in the economic development (Arnds & Bonin, 2002; Little & Triest, 2001; Wilkowska, 2015).

The globally increasing number of people aged 60 years and over as well as the extended life expectancy result in the increased likelihood of chronic diseases which, according to WHO, mostly manifest in the later stages of life (WHO, 2003). Consequently, less people are contributing to health and welfare systems that more and more people depend on. This fact is connected to a substantial increase of costs in the area of healthcare and nursing services (Little & Triest, 2001). In addition to the financial bottlenecks due to the increasing treatment and nursing requirements, some issues from the medical supply chain arise. In the last decades, several weaknesses in the German healthcare system have become

Aging, Technology and Health. DOI: http://dx.doi.org/10.1016/B978-0-12-811272-4.00001-4

apparent (Leonhardt, 2006; Wilkowska, 2015). A combination of lower fertility rates and higher longevity of the society results in a number of those needing nursing care which is significantly higher than the number of persons who can offer the health support. This applies to physicians as well as nursing staff (Korzilius, 2008; Terschüren, Mensing, & Mekel, 2012).

These facts and the resulting challenges in various public spheres require effective, innovative, and efficient solutions. To obviate, as far as possible, the onset of chronic illnesses in the graying society, long-term prevention measures, constant health monitoring, and early diagnostics gain importance. These actions to be taken are the first step to generally achieve better health and, at the same time, to reduce health-related costs. For instance, targeted prevention programs regarding fitness and/or diet regulation can be realized during younger ages of individuals. For those who already suffer from a chronic condition (CC)—and this topic is specifically addressed in the below presented studies—a powerful disease management should be established (i.e., a sensible, as much as possible unobtrusive monitoring of relevant vital parameters and a continuous dialog with the supervising medical staff). Moreover, an efficient system should be created to include supply structures as well as inpatient and outpatient, curative, rehabilitative, and nursing services.

One possible solution to achieve such ambitious goals lies in the use of technology or, more specifically, of advancements in ubiquitous computing in combination with sophisticated, intelligent sensor networks (Holzinger, Röcker, & Ziefle, 2015; Nehmer, Becker, Karshmer, & Lamm, 2006; Yan, Huo, Xu, & Gidlund, 2010). Modern technologies which are integrated in home environments have a huge potential to assist elderly and individuals with CCs in their daily life: They can support their independency, sovereignty, and autonomy, uphold their social network, and maintain the comfort of living in familiar surroundings, rather than relocate in a nursing home or a long-term rehabilitation clinic (Wilkowska, 2015). Technologies that support health, well-being, a balanced and satisfactory lifestyle, be it sports programs, serious exercise games, appropriate dietary programs and/or a vital parameter monitoring system individually adapted to the inhabitant's needs, are feasible and can be realized even with existing devices.

In the areas of health prevention, cure, and rehabilitation, electronic health (eHealth) and electronic homecare (eHomecare) provide a meaningful framework for both the users and the healthcare that is useful to be focused from the user-centered perspective. Taking as an example diseases with the highest prevalence in today's society, cardiovascular diseases—e.g., acute cardiac infarction, cardiac insufficiency, disturbed blood flow through cardiac muscle—are the leading cause of death in Germany, causing a total of about 40% of all deaths (Destatis, 2014). According to experts, people who have suffered from a cardiovascular disease are, firstly, urged to regularly monitor their vital signs, such as blood pressure, heart rate, body weight, temperature, and coagulation. Secondly, these persons must, under certain circumstances, strictly adhere to their prescribed medication intake, follow special dietary requirements, and absolve trainings to maintain physical health (Klack et al., 2011; Lee, 2010). Here, eHealth technology embedded in their home environment could assist with many of these obligations commonplace for heart patients or vulnerable persons, e.g., the storage and transmission of the health data (Eloy, Plácido, & Duarte, 2007). The two empirical studies presented later in this chapter leverage such assistive home environment that supports its inhabitant(s) to meet their health requirements.

To reach a successful adoption of health-supporting technologies, however, high acceptance, high perceived meaningfulness of its use, and, therefore, high intention to use are needed. According to the Extended Unified Theory of Acceptance and Use of Technology Model (UTAUT 2; Venkatesh, Thong, & Xu, 2012), the use behavior is directly linked to the behavioral intention to use a technology system which, in turn, is modeled by different influencing factors, such as, among other things, expected performance of the system, hedonic motivation to use it, and social influence, which can be reached by using it. In addition, the intention to use technology is moderated by user factors, like age and gender which considerably impact on the willingness to use such technologies (Wilkowska, Gaul, & Ziefle, 2010; Wilkowska, Himmel, & Ziefle, 2015; Ziefle & Schaar, 2011). Using UTAUT 2 as a theoretical framework, the two presented research studies dedicate special attention to the user factors and identify perceived benefits and barriers that relate to the acceptance of two distinct healthcare applications.

A consequent consideration of the users' perceptions on technology innovations and their acceptance to use novel technologies—especially in the area of health-supporting ambient technologies—is particularly important for older users as the main target group of homecare environments. It has been shown that seniors desire to keep a livelong independency in their own "four walls" as this allows for a higher life quality in a conversant environment (e.g., Wilkowska & Ziefle, 2011) and preservation of their intimacy, self-reliance, and autonomy, as opposed to living in an old peoples' homes (Dewsbury & Edge, 2001; Mynatt, Melenhorst, Fisk, & Rogers, 2004). In this regard, the idea of technology-enhanced homes fits perfectly with older adults' attitudes. However, on the other hand, older adults were found to face greater difficulties in general in dealing with technology. A high usability of devices in line with smart interfaces are vital prerequisites of universal access (Pak & McLaughlin, 2010; Pak, Price, & Thatcher, 2009), seniors' perception of the usefulness of such a technology, and, eventually, making use of the technology (Pak & McLaughlin, 2010; Wilkowska & Ziefle, 2009). In addition, older adults' experience with technology is grounded on completely different forms, appearances, and types of technologies which do not match the seamlessly integrated smart home technology (Arning & Ziefle, 2007a; Gaul & Ziefle, 2009). The ambient technology which is possibly not even visible for them (as it is integrated into the surrounding) could elicit unfamiliar and even embarrassing feelings. In the traditional view, the home environment is highly intimate and perceived as being safe and comfortable. For older adults and their mental model of technology this seems to be not easily combinable with smart care technology as an integral part of their living space. In this context, privacy concerns and supposed loss of intimacy as well as the feeling of being continuously monitored is a serious barrier (Wilkowska et al., 2015; Ziefle, Himmel, & Wilkowska, 2011). Nobody likes a vision of technology that stigmatizes them as old, ill, and dependent, particularly since there is still a quite negative image of elderly prevailing in public perceptions of societies as well as in working and family environments (Iweins, Desmette, Yzerbyt, & Stinglhamber, 2013; John, 2013; Ziefle & Schaar, 2014). Thus, from a social point of view, the integration of technology into the sanctuary of the "own four walls" is a delicate issue and needs to be developed with sensitivity (Stronge, Rogers, & Fisk, 2007; Wilkowska et al., 2015; Ziefle & Schaar, 2014; Ziefle et al., 2011). Understanding older adults' concerns, their requirements, social values, and hopes in the context of a technology that really supports them is inevitable (Ziefle & Schaar, 2014). Thus, a successful adoption of smart-home technologies is inextricably linked with an understanding of the users, but also their unhesitant willingness to use and integrate technical devices in their personal spaces.

The research objectives and chapter structure

The main aim of this chapter is to show our idea of a smart home: An environment that contains useable medical applications merged into one ubiquitous system that can simplify its users' life in different areas. The main research goal was to examine intention to future use of different health-supporting applications after interaction with them in an experimental setting. We describe two studies, referring to the evaluation of two exemplary applications: Firstly, to the health aspect based on measurements of vital parameters necessary in case of a cardiovascular disease (see "Study I: Health assistance at home" section), and secondly, to the aspect of a person's physical mobility in the context of serious games (see "Study II: Serious exercise games in AAL" section).

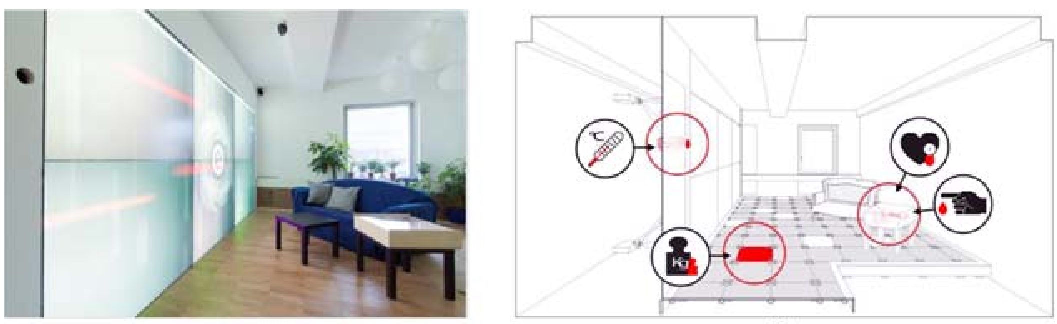
Both applications were created using the design process by Gould and Lewis (Gould & Lewis, 1985) that builds on three principles: (1) Early focus on the users and their tasks; (2) An iterative design process; and (3) empirical measurement of the product use. For a better understanding, we introduce Maria who is an (imaginary) prototypic inhabitant of the smart home. Maria is one of several archetypal personas, a common method in user-centered design (Cooper, 1999), that guided the development of the Ambient Assisted Living (AAL) Lab between participatory user studies. As a potential persona (LeRouge, Ma, Sneha, & Tolle, 2013) in terms of a prototypic older adult as target user of smart home technology, Maria is 74 years old, lives alone, and, as a result of a cardiac infarction she suffered a few years previously, she must keep track of some vital parameters daily (i.e., blood pressure, weight) and consult her doctor within certain time intervals. Additionally, she has some mild, age-related physical impairments, but she is generally in relative good health and interested in maintaining her independence within her "own four walls."

The two studies reported subsequently in this chapter will show meaningful health applications for persons in similar situations and with comparable ailments as Maria. In the first one, a health-assistive application that is embedded into the living environment and allows to monitor relevant vital parameters is evaluated. The intention to use the health-supporting ambient technology after an interaction with the system is the main research subject. The second study reports on serious games for physical exercise in the technology-augmented habitat. Here, apart from the rendered performance and factors influencing the willingness to play the game, factors affecting the intention to use the ambient technology in the entertaining context will be presented.

Future Care Lab© and its applications as experimental environment

The studies to be described in the following were conducted in the Future Care Lab© at RWTH Aachen University. This environment resembles a living room of comfortable size (25 m^2) and enables the integration of different existing and prototypic medical technologies. Following the user-centered design approach (Gould & Lewis, 1985), this environment is used to include the users' perspective into the design and development of upcoming medical technologies, since their feedback is very valuable for the desired user acceptance and can be integrated into later stages of the design process. In the next iterative cycle then, a further evaluation and optimization of the ambient system begins (participatory design approach).

The idea was to make use of currently available technologies and integrate them into an overall consistent usage concept. Thus, the Future Care Lab© was meant to be a medical and living environment at the same time: i.e., the room should, on the one hand, provide the necessary medical equipment and assistance features without compromising comfort, and, on the other hand, preserve the intimacy and personal privacy of a living room (Klack et al., 2011). For the communication interface, which is the key requirement for remote diagnostics and communication between patient and physician, the room was equipped with high-definition cameras and a wall-sized interactive display as presented in Fig. 1.1. The multi-touch, sensitive display-wall serves as a screen and an input device for various applications (Heidrich, 2015; Kasugai, Ziefle, Röcker, & Russell, 2010), ranging from monitoring of relevant health parameters, medication, nutrition, and exercise management



(A) (B)

Figure 1.1 Future Care Lab© with its interactive wall display, serving as the visual communication tool and a diagnostic interface in the patient–doctor communication: (A) unobtrusive interior of the living lab environment, (B) schematic visualization of the health-monitoring system (side table: blood pressure and coagulation; wall: body temperature; floor: weight).

to daily multimedia entertainment (e.g., serious games (Brauner, Holzinger, & Ziefle, 2015), movies), virtual environments (e.g., myGreenSpace, meetingMeEating (Röcker & Kasugai, 2011)), or meetings with physicians, family, and friends (Beul et al., 2010). Focusing on the health aspect (the main objective of the Study I described later) this feature allows the inhabitant to measure vital signs and easy access their data as well as their medication histories without using different devices and without having to manually recording the results for a (video) consultation with their physician.

The term Ambient Assisted Living (AAL) describes the basic idea behind the development of the living lab: A space to foster the emergence of systematic innovations for the autonomous living of elderly and individuals with chronic illnesses which, on the one side, increases the quality of their lives, and, on the other side, reduces the expenditures of the possibly necessary nursing care. Such smart homes that include innovative smart health concepts, reaching from electronic health monitoring to serious gaming as will be described in the second study, are meant to be individually suited to the resident(s), adaptive to the (changing) needs (e.g., disease progress), and sensitive with regard to the living conditions (Klack et al., 2011).

Study I: Health assistance at home

The first study was intended to examine if potential users, after a real interaction with the health-supporting application, would use such assistive systems at home in the future. For this purpose, an experimental study with middle-aged and older individuals was performed in the Future Care Lab©. The target group were persons with chronic heart conditions, who have to monitor some of their health parameters on a daily basis. Their opinions were compared to those of individuals without any ailments.

Getting back to the example of Maria, the main question was whether she intends to use the application in the future, which is meant to simplify measuring and recording her vital parameters, ease the storage of her health data, and facilitate communication with the responsible physician in case of deterioration of the relevant values. In the following, the experimental design and procedure of the first study are described.

Materials and methods

Research method

As the aim was to get an impression of the real use of the assistive system, this study was designed to examine how persons with chronic heart conditions can effectively monitor their relevant vital signs by means of unobtrusively integrated specific medical devices in a domestic environment. For this purpose, the participants were asked to perform two exemplary measurements, common for heart patients: The first was taking their blood pressure (via a standard sphygmomanometer, comprising an inflatable cuff to restrict blood flow and a manometer to measure the pressure), the second was a weight measurement (via a digital scale integrated in the floor). Both are, according to experts, reliable parameters for (negative) changes in cardiovascular processes of the human body. Participants were requested to use the health-app of the system (Fig. 1.2A, top left) which initiates the particular measurement and, afterwards, to appropriately save the data in the system. The app also provides the possibility to compare the current result with previous results (imaginary but strongly related to the real one) in a measurement overview (Fig. 1.2B, bottom right).

Between the trials and after interaction with the health application of the system, the individuals were asked to assess if they would use such technology at home, provided that the circumstances are acceptable—i.e., transparent financing, technical maintenance, telemedical servicing. In a semistructured interview as well as using the method of a quantitative questionnaire, participants answered questions such as: "Can you imagine using an eHealth system like this in your home in the future?" and "Do you think you would like to frequently use such technology system in the future?" The questions based on the original items for behavioral intention in UTAUT 2 (Venkatesh et al., 2012) were adjusted to the purposes of the present study. The statements in the questionnaire had to be rated on a five-point Likert scale ranging from "strongly disagree" (=1) to "strongly agree" (=5). In addition, opinions about the system's usability, assessed via the System Usability Scale (Brooke, 1996), and general perceptions pertaining to the reliability of the system, data security, and personal privacy were collected (for details see Wilkowska, 2015).

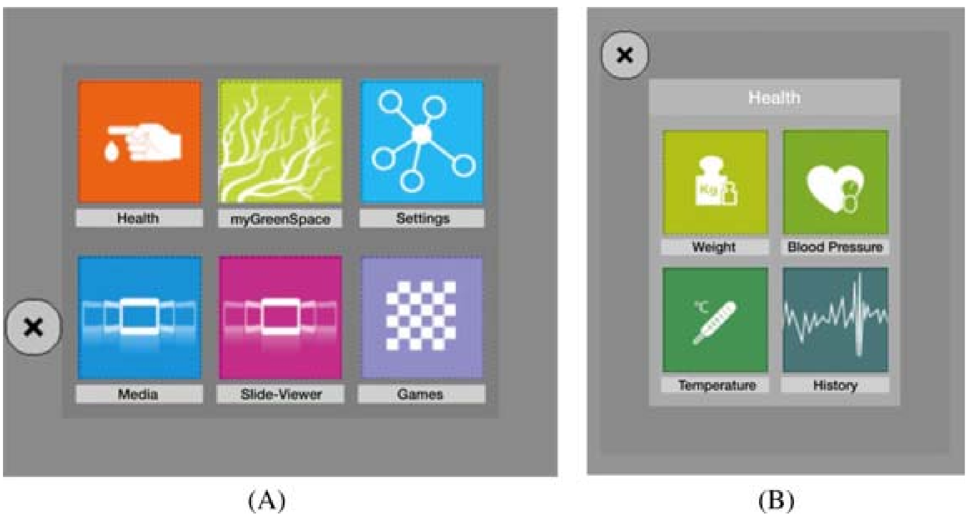


Figure 1.2 Control panel on the large wall screen in the Future Care Lab©: (A) front panel for different applications; (B) the health-app tailored to Marias needs of monitoring vital parameters relevant for the cardiovascular system.

Experimental procedure

Experimental testing was carried out within a period of about two weeks. The sessions were held individually and in German, the native language of all participants. Before the experiment started, each participant was asked about special needs as well as objections or restrictions with respect to the planned study. The experimental trials took on average 20−30 minutes.

In the first step, the participants were introduced to the concepts of AAL and telemedicine to provide an idea of the broad possibilities connected to eHealth technology in a domestic environment. Monitoring of vital parameters in a comfortable way at home and the reminder function to do so, an efficient digital transmission of the sensitive health data, facilitated patient−physician communication and exchange with other patients or support groups on the Internet. To evaluate the interaction with the technology, participants had to perform two tasks—taking their blood pressure and body weight using the health-app on the system. Each action was previously demonstrated by the experimenter. After each measurement, the participants were requested to interact with the app by taking a look at the weekly or monthly overview of particular results. Fictitious values for the previous weeks and months were generated automatically, using an algorithm based on the real measurement. During the interaction, the participants were informed that the storage and transmission of their personal health data would take place via secure, specialized medical services which would facilitate the communication with medical staff. There was also no time limit for the user's interaction with the health-app. After each measurement and the subsequent interaction, participants assessed the functionality and usability of the system. They also filled in a questionnaire to evaluate their willingness of using the technology in future (as described in "Research method").

In the final part of the experimental session, interviews gave participants the opportunity to comment on their perceived advantages and disadvantages in comparison to current solutions in the healthcare sector. This gave the researchers an idea of the general attitude toward the future use of such complex and sophisticated technologies in the domestic setting.

Participants of the Study I

To get volunteers to participate in this experimental study, posters were placed in local hospitals in cardiology departments and public places for about three weeks. Attending the experiment was voluntary and was neither compensated with payments or other incentives, nor were any direct or indirect health benefits promised or suggested to the test group.

A total of 25 German adults between the ages of 35 and 86 years ($M = 61.1$, $SD = 12.4$) participated in the study, 56% of them female. More than half of the participants (52%) reported to suffer from some kind of chronic heart disease (e.g., tachycardia, myocardial infarction, coronary heart disease), and as many to regularly visit a physician to check their actual health status. In the group with chronic conditions (CCs), all persons used medical assistive devices to monitor relevant vital signs (e.g., blood pressure, heart rate, weight, body temperature); the majority (70%) reported to write down the results of the measurements by pen and paper. In the group with healthy participants (H), only one person reported to use medical devices on a regular basis and to visit a physician periodically for checkups.

The participants presented different educational levels: 52% reported a university degree (including business administration, domestic science and nutrition, psychology, mechanical engineering, teaching profession, biology, etc.), 20% completed a vocational training, and 28% indicated secondary school qualifications. When asked about their current or last profession before their retirement, various occupational fields were named, e.g., psychologists, doctor's assistants, engineers, administrative assistants, teachers, business economists, translators, etc. In this way, the presented study reflects a broad spectrum of users.

Research variables

To examine the intention for a future use of the eHealth technology by different users, the following research variables were involved in the statistical analyses.

Independent variables: The first independent variable was the age of the tested persons. Here, middle-aged (age range: 35−59 years; $M = 51.4$, $SD = 6.6$; $n = 13$) and people in the older adulthood (age range: 60−86 years; $M = 71.6$, $SD = 7.7$; $n = 12$) were compared. In addition, the participants' self-reported health status (chronic heart condition ($n = 13$) versus healthy/without heart condition ($n = 12$)) distinguished between the participants. Also, gender-specific perceptions (males ($n = 11$) vs females ($n = 14$)) were contemplated in the analyses.

Dependent variables: The main focus lies on the intention to use (ItU) the complex but, at the same time, versatile technology which is integrated into the residential area. Methodologically, this topic is considered from both the qualitative and quantitative point of view. In the quantitative analysis, the two assessments about the intention to use eHealth in the future, evaluated after each measurement event, were merged to form a single variable (ItU: min. = 2, max. = 10). The other dependent variables are the fun ("I had fun using the system") and the perceived meaningfulness of the use ("I consider the monitoring of my vital parameters (e.g., blood pressure and weight) with the help of integrated technology at home reasonable"). The latter two had to be rated on a five-point scale as described earlier.

Results of Study I

The results of the first study mainly focused on the users' intention to use complex assistance technologies in a smart home environment, here exemplified by the health context as to allude to the strain of increasing numbers of older people and persons who need medical monitoring. In the following, it is firstly analyzed how the intention to use such eHealth technology correlates to the enjoyment of its use and its perceived meaningfulness, as well as how all the research variables are connected. Secondly, it is examined whether there are fundamental differences between users who either promote or negate the intention to use the system. Thirdly, a qualitative analysis will provide a complementary picture of the opinions about intended future use.

For the analyses of the results, different statistical techniques were chosen, depending on the properties of the data, number of the variables and groups, and in accordance with the achievement of the statistical assumptions. When possible, parametric methods were preferred. The cut-off for the significance level in all statistical analyses lies by 5% ($P = .05$), the effect size is calculated with eta squared (η^2), the values of which can range from 0 to 1 and indicate the strength of effect sizes (Cohen, 1988).

Relationships between research variables

To gain a general impression of the associations between the research variables, Pearson product–moment correlation coefficients (parametric analysis between continuous variables) and Spearman's rho correlation coefficients (nonparametric alternative) were generated, depending on the respective data structure. Table 1.1 summarizes the strengths of the particular relationships.

From the correlation analysis' results, it is evident that age is strongly associated with the intention to use the ambient technology ($r = 0.53$, $P < .01$) and with the meaningfulness of its use ($r = 0.40$, $P < .05$), which means that both get higher with increasing age. The above coefficients affirm the fact that with increasing age the occurrence of the chronic heart diseases grows ($r = 0.48$, $P \leq .01$), and there is a substantial positive association with the intention to use the eHealth technology ($r = 0.43$, $P < .05$): Persons with chronic heart condition showed higher willingness to utilize it than the healthy participants. In contrast, for gender there is no evidence of links to the focused aspects (*n.s.*).

From Table 1.1, also high positive relationships between the focused dependent variables become evident. The intention to use the technology is positively related to the perceived meaningfulness of use ($r = 0.42$, $P \leq .05$) and fun ($r = 0.49$, $P \leq .05$); the latter two, in turn, are strongly associated with each other ($r = 0.63$, $P \leq .001$).

Table 1.1 Bivariate correlation coefficients between the research variables (gender: male = 1, female = 2; health status: healthy = 1, chronic heart condition = 2) ($N = 25$)

	Age	Gender	Hs	ItU	F	M
Age	1	–	0.48*	0.53**	0.13	0.40*
Gender		1	–	−0.07	0.15	0.09
Health status (Hs)			1	0.43*	−0.15	0.22
Intention to Use (ItU)				1	0.49*	0.42*
Fun (F)					1	0.63***
Meaningfulness (M)						1

***$P < .001$; **$P < .01$; *$P < .05$.

These substantial relationships among the target variables give reason to take a closer look at the effects of different users on the future usage behavior in the health context.

User differences

In the next step, the effects of the independent variables on the intention to use, fun, and perceived meaningfulness with respect to the use of ambient health-supporting technology are examined. To compare the research groups according to the properties of the data, independent-samples *t*-tests were used.

Since, in the context of eHealth technology, the *physical health* of the inhabitants can be decisive for an opinion of its use, the first analysis refers to a comparison between persons with chronic heart conditions and healthy individuals. The *t*-test revealed significant differences with respect to the intention to use eHealth in the future between these research groups [$t(23) = 2.3$, $P = .033$, $\eta^2 = 0.17$]. Those who suffered from illness wanted, almost without exception, to use the technology in the future ($M = 9.7$ out of 10 points, $SD = 0.6$). In the healthy group, the opinions in this regard were positive too, but much less pronounced ($M = 7.7$, $SD = 3$). The mean differences are depicted in Fig. 1.3. Apparently, all participants had a positive attitude towards the technology innovation as the average values were high. However, people with chronic diseases see more benefits in the use of technical assistance (at least in the context of the health-app) in comparison to persons without permanent ailments. Moreover, the health status had no significant effect on the perceived fun with the technology [$t(23) = 1.1$, *n.s.*] and the perceived meaningfulness of its use [$t(23) = 1.2$, *n.s.*].

In addition to the health aspect, it is also of interest whether the *age* factor influenced the opinions about willingness for future use of a medical assistance system in the home environment. The analysis revealed that the examined age groups significantly differed in regard to the intention to use [$t(23) = -2.5$, $P = .025$, $\eta^2 = 0.22$] and the perceived meaningfulness of the use [$t(23) = -2.9$, $P = .012$,

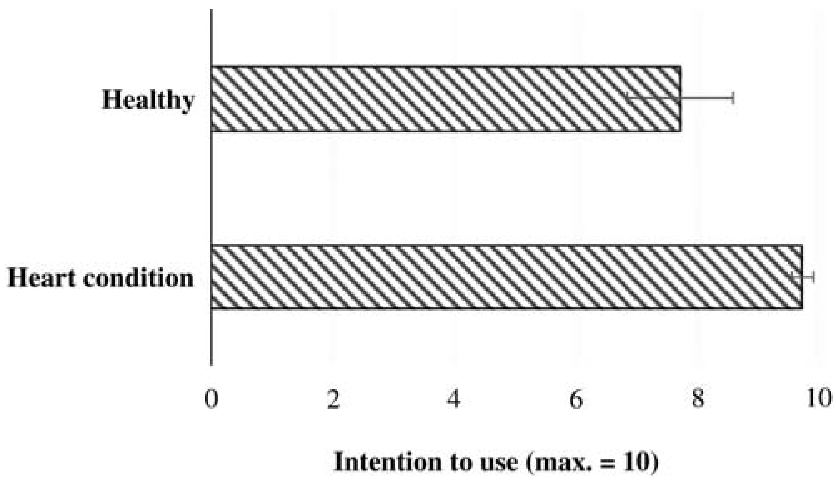


Figure 1.3 Main effect of the health status on the intention to use eHealth technology at home [$t(23) = 2.3$, $P < .05$].

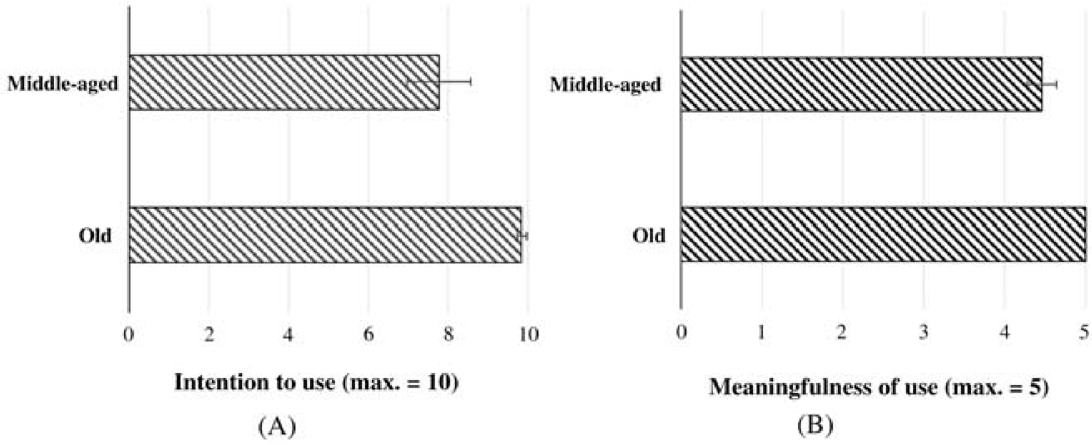


Figure 1.4 Main effect of age: (A) on the intention to use eHealth technology at home [$t(23) = -2.5$, $P < .05$]; (B) on perceived meaningfulness of use [$t(23) = -2.9$, $P < .05$].

$\eta^2 = 0.26$]. Here, older participants showed averagely higher, almost the maximum possible intention to use eHealth ($M = 9.8$ out of 10 points, $SD = 0.4$) and considered the monitoring of their vital parameters by means of the medical assistive system invariably more meaningful ($M = 5$ of 5 possible points, $SD = 0$) than the middle-aged individuals (ItU: $M = 7.8$, $SD = 2.9$; meaningfulness: $M = 4.4$, $SD = 0.7$). The effect of age is visualized in Fig. 1.4. With respect to the evaluations of fun after the interaction with the system, both age groups showed high mean values (middle-aged group: $M = 4.6$, $SD = 0.8$; old age group: $M = 4.8$, $SD = 0.4$); the differences were not significant [$t(23) = -0.9$, *n.s.*].

In the final step, it was examined whether the *gender* factor influenced opinions in a relevant way. The independent-samples *t*-test analysis revealed no statistical significance for gender differences [ItU: $t(23) = -1$, *n.s.*; fun: $t(23) = 0.6$, *n.s.*; meaningfulness of use: $t(23) = 0.7$, *n.s.*]: Men and women reached similarly high mean values in all the mentioned aspects. These results testify that, unlike previous technology generations, gender no longer splits the users with respect to the latest technological achievements. On the contrary, women and men are equally willing to use, have comparable fun with, and consider the technical medical assistance at home meaningful to the same extent.

Intention to use eHealth: Qualitative analysis

To complement the research analysis, in this section a brief report of the qualitative results will be offered. The benefits of qualitative methods, like interviews, are not only a far more personal form of research, but working directly with the respondent eases the expression of opinions and impressions, and it also allows for follow-up questions or redirection if someone strays from the topic.

As was described in "Experimental procedure" section, after the interaction with the ambient assistive system in the Future Care Lab© and the subsequent completion of the questionnaire, participants were involved in a short, semistructured interview. Therein, they had to respond, among other things, to the question whether they could imagine (or not) using a technical system like the one used in the test experiment in their homes in the future.

According to the final statements, more than three quarters of the participants ($n = 19$; which makes 76%) showed a positive attitude towards the (future) use of the system after their interaction with the prototypic eHealth environment. In the following, some exemplary statements are listed:

> *I think it is totally fine! Luckily, until now I hadn't had to deal with bigger health issues, but I think that has a future and I can imagine to use it not only in the health context.*
>
> *(male, 53 years, no chronic conditions)*

> *I think, when the technology is fully developed and it works properly, the results of the measurements would be absolutely reliable. If I had that, I would also regularly measure my blood pressure, like I also should. In this form, it is too large for my apartment, but I think it's great and I would definitely use it in the future.*
>
> *(female, 56 years, hypertension)*

> *That's really interesting and also fun! I could certainly use it.*
>
> *(female, 73 years, no chronic condition)*

Another 20% of the interviewed persons ($n = 5$) displayed a positive attitude, but they also showed a certain skepticism, or declared some reservations for the future use. Below some examples are listed:

> *You certainly can learn how to use that thing, but most people are reluctant to deal with it; my wife, for example. I think it is very good, however, space limits and the financing could be reasons not to use it.*
>
> *(male, 74 years, cardiac insufficiency)*

> *I think it's great that you can operate it with the whole hand (instead of only one finger). But I would like to see additional functions: electronic calendar, reminder, etc. You could also retrofit the floor.*
>
> *(male, 71 years, myocardial infarction, stroke)*

One person rejected the use of the ambient system in the future:

> *Human contact gets lost, the sensory organs come off badly, life would be very mechanized. That's not for me! I'm less concerned about my health monitoring than about the [social] isolation.*
>
> *(female, 58, arrhythmia, tachycardia)*

Summary of the results for the Study I

According to the presented results, the greatest enthusiasm for the use of health-related technology in terms of ambient assistance systems in a domestic environment emerges from elderly and chronically ill people. Their intention to use such ambient technology is significantly higher than in healthy and individuals in their midlife, even though the vast majority of participants acknowledged it as a meaningful and enriching supplement. The participants showed great enthusiasm with the technology, reaching mean values between $M = 4.6$ and $M = 4.8$ out of maximum five points. In addition, the absence of significant effects for gender indicates that women and men comparably evaluate the technology with respect to the focused aspects.

Accordingly, we can assume that Maria is pleased with the surrounding technology in her home and she enjoys taking her vital signs regularly. She definitely wants to use this innovation in the future.

Study II: Serious exercise games in AAL

After the measurement of her vital parameters, Maria is interested in playing a game. The technology-augmented habitat provides different types of games. Maria can choose to play conventional computer games, or she might use one of the several serious games for healthcare offered by the AAL environment. One serious game couples the motivational incentives of games with explicit and thought-out purposes outside the actual game (Zyda, 2005). For example, the game Cook It Right (Wittland, Brauner, & Ziefle, 2015) uses a cooking scenario to address the improvement of cognitive functioning, i.e., remembering and planning abilities. Maria decides to launch the exercising game Fruit Garden this time.

Physical inactivity is linked to diabetes, hypertension, coronary, and cerebrovascular diseases. It is also connected with a lower life expectancy (Knight, 2012). In contrast, exercising has benefits for health, such as lower risk and lower intensity of cardiovascular diseases (Perez-Terzic, 2012), higher physical and cognitive abilities (Ahlskog, Geda, Graff-Radford, & Petersen, 2011), as well as positive influences on mood and depression (Thayer, Newman, & McClain, 1994). Sportive physical activities reduce the probability of silent brain infarcts (Willey et al., 2011). Therefore, performing regular exercises—in or outside a game environment—is beneficial for the overall health status.

The Fruit Garden game involves full-body movement exercises, captured with nearly invisible motion-capturing cameras, and aims at picking fruit in a garden environment presented on the large wall of the technology-augmented habitat (Brauner et al., 2015; see Fig. 1.5). Previous research (De Schutter & Van Den Abeele, 2008) has identified this as a suitable game core. In several levels with increasing difficulty, distinct movement gestures address different body and muscle areas and the training should retain, or improve, the overall stamina of its players. The game offers different single and multiplayer modes, and players can decide to compete against their own high scores or against friends, relatives, or others over a network. Today, Maria chooses to play the single player mode, as she wants to break her personal record for the levels with more difficult movements.

Figure 1.5 An elderly player interacting with a prototype of the fruit picking game.

Materials and methods

To investigate how people interact with an exercise game in a technology-augmented environment, and to understand under which conditions it is likely to be used, a formal user study was conducted. This section presents the evaluated prototype of the above mentioned exercise game, followed by the description of the independent, explanatory, and dependent variables. Finally, the sample of the experimental study is described.

The evaluated game prototype

In the exercise game, the player's task is to pick different fruits (e.g., apples, pears) in a comic-like garden environment presented on the large wall of the AAL lab. The body movements are captured through hidden Kinect sensors, which capture a high resolution color image, a depth image, as well as a skeleton model with 3D coordinates of 20 joints in high temporal and spatial resolution. The picture of the player is directly integrated into the game environment by compiling the different images from the Kinect sensor (see Fig. 1.6): The RGB-image of the player is separated from the background by using the depth image, then the background-separated image is integrated into the game's scenery.

For each type of fruit, a specific full body movement gesture is required. The gestures were developed with medical professionals and each gesture captures a specific, medically sound, exercise. For example, for picking an apple on the right side of the screen, the left hand must be used. This trains hand-eye-coordination and the shoulder and back muscles. During the first levels of the game, the different gestures are sequentially introduced and repeatedly trained.

Research variables

Before and after the serious game intervention, a questionnaire assesses the independent (explicitly used for creating the sample), explanatory (measured but not

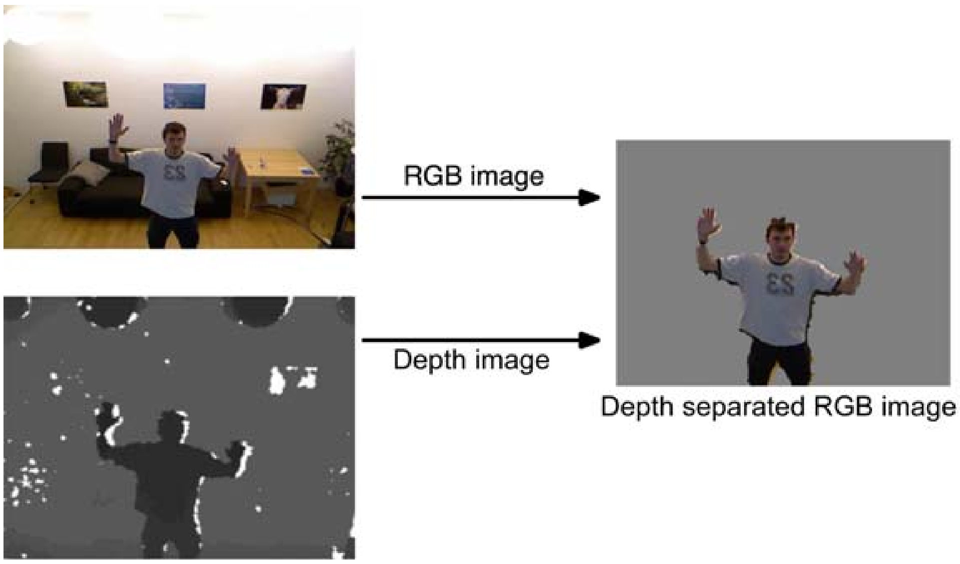


Figure 1.6 Schematic illustration of the separation of the player's background using the depth image.

used for creating the sample), and dependent variables (capturing the evaluation of the game) of the user study.

Independent variables: Besides age and gender as independent variables, the questionnaire collected data regarding the participants' self-efficacy in interacting with technology (SET, e.g., "I have fun solving technical problems"), their gaming frequency across multiple game types (GF, e.g., "I frequently play board games"), and their need for achievement (NAch, e.g., "I am attracted to difficult problems") as additional explanatory variables.

Self-efficacy in interacting with technology relates to Banduras Self-efficacy Theory (Bandura, 1982) and describes an individual's perceived ability to successfully interact with a technical device and to attain certain goals with these devices. Previous research has identified tremendous gender (e.g., Brauner, Leonhardt, Ziefle, & Schroeder, 2010; Busch, 1995; Wilkowska et al., 2010) and age effects (e.g., Arning & Ziefle, 2007b; Wilkowska & Ziefle, 2009) in performance and acceptance of technological systems. Self-efficacy in interacting with the technology was measured and analyzed by the scale of Beier (1999).

Gaming frequency was determined as an index across nine playful activities ranging from playing cards or ball games (not computer mediated), to computer or console games.

The participant's need for achievement was measured on a scale by Schuler and Prochaska (2001). An individual's need for achievement relates to the choice of tasks and the performance attained within the tasks. Therefore, players with higher need for achievement will attain a higher performance in the game than players with a lower need for achievement.

Dependent variables: In addition to the aforementioned personality factors, the participants' current subjective pain levels for several body parts (e.g., head, shoulder, back, legs) and the perceived current level of exertion—collected on the scale by Borg (1982) that strongly correlates with the actual heart rate—were queried. To investigate the effect of the game on perceived pain and exertion, both measures were captured directly before and after the game intervention (repeated measure).

The evaluation of the game was measured using the items of the Technology Acceptance Model (TAM (Davis, 1989; Davis, Bagozzi, & Warshaw, 1989)) and the Extended Unified Theory of Acceptance and Use of Technology (UTAUT 2 (Venkatesh et al., 2012)). Following Davis' TAM model, there is a strong relationship between the intention to use a system and the later actual system use. Therefore, the intention to use (ItU)—similar to the first study—is captured as the target variable to predict the actual use of the system (e.g., "I intend to continue using this game in the future"). A detailed description of the other constructs of UTAUT 2 for this exercise game is given in (Brauner et al., 2015).

In addition to the participants' assessments of the game, the attained performance was captured via log files and then combined with the data from the questionnaires. All items, apart from age and gender, were rated on a six-point Likert scales ranging from "I fully disagree" (=0) to "I fully agree" (=5). The acquired data is analyzed using bivariate correlations (Spearman's rho (ρ) coefficient is reported), univariate analysis of variance (ANOVA) and repeated measures, as the data meets the assumptions of parametric calculations. Effect sizes are reported as η^2, corresponding to the first study. Multiple linear regressions were calculated using the step-wise method and models with high variance inflation factors were excluded (VIF $\gg 1$). The level of significance is set to $P = .05$.

Participants

In total, $N = 64$ participants ($n = 32$ males and $n = 32$ females) ranging from 17 to 85 years of age participated in the user study voluntarily and without any financial compensation. The participants were gathered through public posters in the city and personal social networks. The reported current or last occupations were in the social (20%), health (8%), business (9%), technical (41%), or other sectors (22%).

As above, the sample was split into a younger ($M = 26$, $SD = 4.6$, age ≤ 35 years) and an older group ($M = 61.6$, $SD = 10.4$, age >35 years) to differentiate between age-dependent evaluations, using factorial methods. By the design of the sample, age groups and gender were not correlated [$\chi^2(2,64) = 0.563$, *n.s.*].

About one quarter of the participants (26%) reported a chronic illness, mainly asthma, hypertension, and diabetes; the prevalence of chronic illness grew with the increasing age ($\rho = 0.41$, $P \leq .001$).

Elderly subjects indicated a lower technical self-efficacy ($\rho = -0.37$, $P < .01$). Also, gender affected technical self-efficacy and women reported significantly lower scores than men ($\rho = -0.33$, $P < .01$). Gender [$F(1,60) = 4.3$, $P = .043$] as well as age [$F(1, 60) = 24.6$, $P < .001$] are significantly related to technical self-efficacy. Though, there is no significant interaction between age and gender [$F(2, 59) = 0.1$, *n.s.*].

The subjective gaming frequency decreased with the increasing age ($\rho = -0.49$, $P < .001$), but gender did not affect the reported gaming frequency ($\rho = -0.16$, *n.s.*).

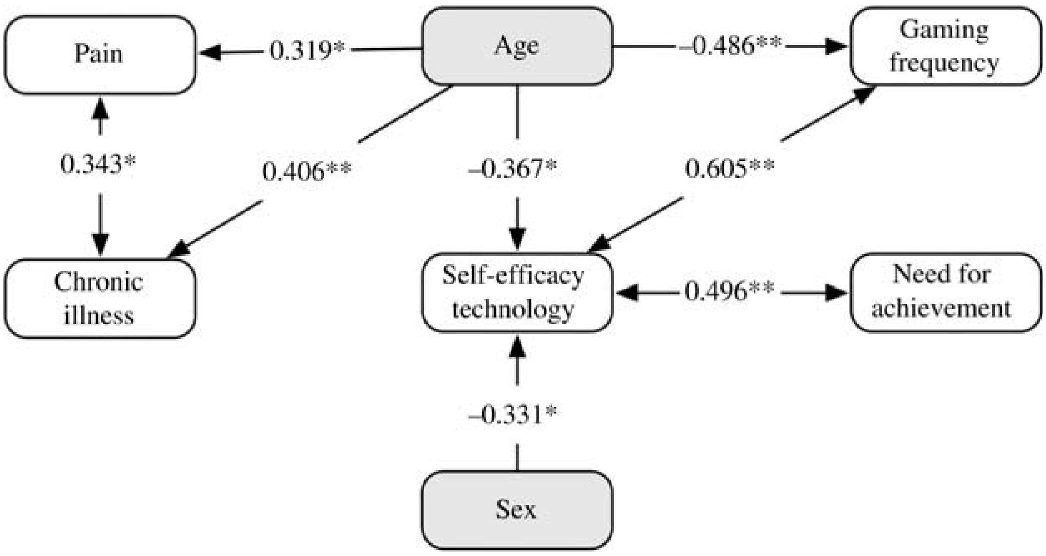


Figure 1.7 Interrelationships between the investigated user factors (**$P < .01$; *$P < .05$).

Although the gaming frequency scale captures the frequency of use of the technology-mediated and nontechnology mediated playful activities, there is a strong positive relationship between gaming frequency and self-efficacy in interacting with technology ($\rho = 0.60$, $P < .001$). Fig. 1.7 depicts the dependencies between the investigated user factors.

Results of Study II

In the results section of the second study, firstly, the overall effect of the game on the perceived pain levels and the perceived exertion is presented. Secondly, the factors that contribute to performance in the game are identified. Finally, the participants' intention to use the game in the future and factors contributing to that are analyzed.

Effects of the game

Exertion: To understand the effect of the game on the perceived exertion, a repeated measures ANOVA with the factors age and gender as independent variables, time as within-subject variable, and perceived exertion as dependent variable was calculated. The analysis reveals that the perceived exertion doubles from $M = 0.8$ ($SD = 1.2$) to $M = 1.7$ ($SD = 1.3$) of 5 points and that this increase is statistically significant [$F(1,60) = 13.3$, $P = .001$, $\eta^2 = 0.182$]. Gender does not affect the change in exertion [$F(1,60) = 0.5$, *n.s.*], but there is a significant effect of age [$F(1,60) = 7.7$, $P = .007$, $\eta^2 = 0.113$]. Specifically, the exertion of the younger participants increases from $M = 0.7$ ($SD = 0.8$) to $M = 2.2$ ($SD = 1$) of 5 points, whereas there is only a negligibly increase from $M = 1.0$ ($SD = 1.5$) to $M = 1.2$ ($SD = 1.1$) of 5 points for the elderly.

Pain: An investigation of the changes of the perceived pain levels further reveals a significant overall effect of the game [$F(1,60) = 20.2$, $P < .001$, $\eta^2 = 0.25$]. On average across all participants, the perceived pain level decreased over the course of the exercise game. Although the absolute decrease from $M = 0.5$ ($SD = 0.6$) to $M = 0.2$ ($SD = 0.3$) of 5 points seems rather small, the relative change of -62% is astonishing. Again, age [$F(1,60) = 6.4$, $P = .015$, $\eta^2 = 0.09$] but not gender [$F(1,60) = 0.4$, *n.s.*] affected the decrease in pain perception and the decrease is stronger for older (-68%) than for younger participants (-33%). The other investigated factors, such as a chronic illness, did not or to a much smaller extent influence the change in perceived pain.

Performance

Only one 85-year-old female participant had difficulties to use the game due to movability constraints. The other 63 participants picked 9–30 fruits in each level of the game, with an average of $M = 19.6$ ($SD = 5.2$) fruits per level ($Md = 20$). All investigated user diversity factors were found to influence the attained performance in the game as shown in Fig. 1.8.

As the description of the sample has shown, all considered factors of user diversity are closely interrelated. To untangle this net of dependencies and to identify the true drivers for performance, a multiple linear regression analysis is calculated. Thereby, the user factors were considered the independent variables and the average performance across the three levels was included as the dependent variable.

The analysis revealed a linear model for performance based on age, need for achievement, and gender that explains over 63% of the variance in performance ($r^2 = 0.63$). The model's parameters are given in Table 1.2.

Intention to use

Now, the important question is whether and under which premises the game is likely to be used by the future residents of technology-augmented habitats. This section provides two perspectives on this question: Firstly, the variables that govern the intention to use the game are identified. Secondly, the evaluation of the game's assessment with regard to the identified influencing factors is presented.

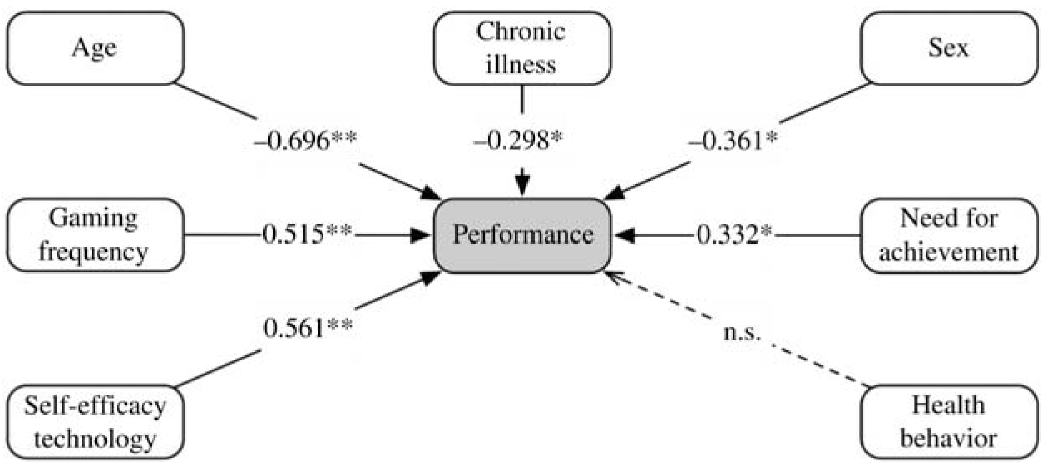


Figure 1.8 User factors contributing to performance (**$P < 0.01$; *$P < .05$).

Table 1.2 **Linear regression model for performance ($VIF_{max} = 1.39$)**

Factor	*B*	SE *B*	*β*	*T*
(const)	26.5	2.03		13.04
Age	−0.17	0.02	−0.66	−8.26
Need for achievement	1.24	0.36	0.27	3.43
Gender	−2.64	0.79	−0.27	−3.34

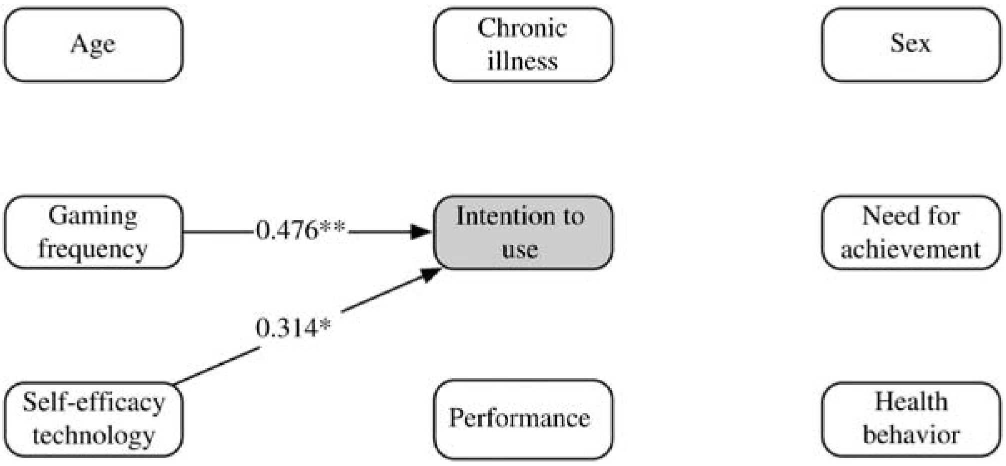


Figure 1.9 User factors contributing to intention to use (**$P < .01$; *$P < .05$).

A correlation analysis shows that the intention to use the game is solely governed by the participant's prior gaming frequency ($\rho = 0.47$, $P < .001$) and their self-efficacy in interacting with technology ($\rho = 0.31$, $P < .05$). None of the other investigated facets of user diversity, like age, gender, chronic illness, or the need for achievement, has a significant influence on the intention to use the game. A considerable finding was that the performance attained in the game is not meaningfully related to the projected later use ($\rho = 0.17$, *n.s.*). Hence, some people might express a desire to play, or not to play, the game again regardless of whether they were rather slow or rather fast in the game. Fig. 1.9 illustrates the two variables influencing the projected use of the game.

A multiple linear regression revealed that the effect of self-efficacy in interacting with technology on the intention to use fades if controlled for gaming frequency. Hence, gaming frequency is the single most significantly influencing factor on the intention to use serious games for healthcare in technology-augmented home environments.

Considering the absolute values of the intention to use the game, overall, the intention is rather high ($M = 3.9$, $SD = 1.2$ out of 5 points) and above the midpoint of the scale (2.5 points). The participants attested that the had game a high entertainment value ($M = 4.6$, $SD = 0.6$ out of 5 points) and wanted to play it again (replay value: $M = 4.3$, $SD = 0.9$). Yet, the desire to use this game in their home was much lower, but still above the center of the scale ($M = 3$, $SD = 1.6$ out of 5 points).

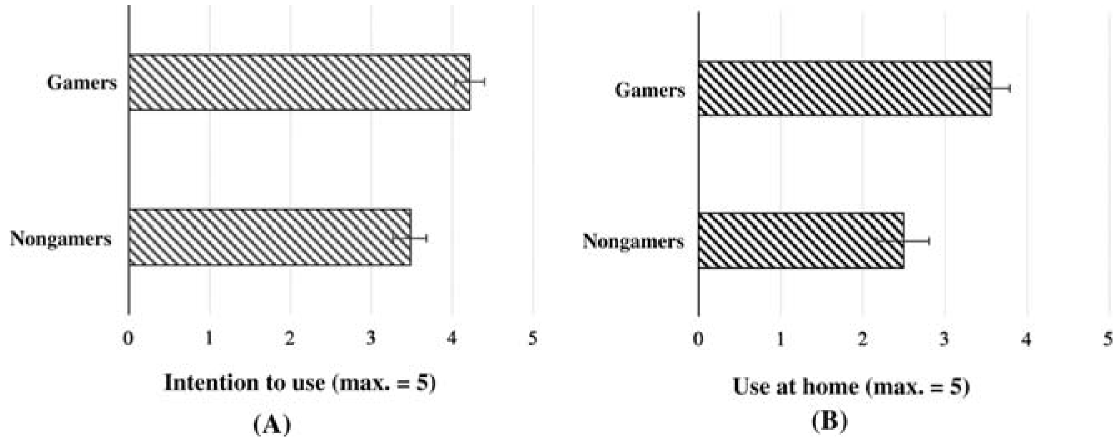


Figure 1.10 Evaluation of the serious exercise game by gamers and nongamers: (A) on the intention to use serious games; (B) on the use at home.

As gaming frequency was identified as the main factor for the intention to use this game in the future, it was further examined whether absolute evaluations differ. The overall intention to use it in future was significantly higher for gamers ($M = 4.2$, $SD = 1$) than for nongamers ($M = 3.5$, $SD = 1.2$) [$F(1,62) = 7$, $P = .010$, $\eta^2 = 0.102$]. However, both gamers and nongamers attested that the game had a similarly high entertainment value [$M = 4.6$, $SD = 0.6$; $F(1,62) = 0.3$, *n.s.*]. Also, the desire to play the game again did not differ significantly between gamer types [$F(1,62) = 3.4$, *n.s.*]. Fig. 1.10 illustrates the relevant findings.

According to the analyses, the participants were less inclined to use the game in their homes ($M = 3$, $SD = 1.6/5$ points) and both gamer groups differed significantly [$F(1,62) = 7.3$, $P = .009$, $\eta^2 = 0.106$]. Gamers expressed a higher desire to play the game at home ($M = 3.6$, $SD = 1.3$) than nongamers ($M = 2.5$, $SD = 1.8$). Surprisingly, the standard deviations on this question were considerably higher in comparison to previous questions which hints at different evaluations among the participants.

Discussion and limitations

In the following, a résumé of the results of both studies will be presented, interpreted, and discussed in terms of smart health. The subsequent section deals with limitations and future research. In this paper, we introduced two different health-related applications for which the broad acceptance and the intention to use these tools in the (smart) home environment were under study, using a strictly user-centered and participatory design methodology. As the above presented studies showed, both chronically ill persons as well as healthy (aged) individuals successfully interacted with the electronic health system integrated into a prototypical living room. In addition, a simulated gaming environment meant to motivate the (older) inhabitants to keep active by physical exercise, was found to increase the intention to use such ambient technologies in the future.

The current results show that, unlike previous trends in the use of technology innovations (where scientific studies have demonstrably revealed that young, mostly male individuals show significantly higher technical interest, knowledge, and skills), the greatest enthusiasm and willingness to use technology in the context of health-related assistance systems in domestic environments emerges from elderly and chronically ill people, regardless of gender. This finding originated especially from individuals with chronic heart diseases who did not only interact with the ambient system smoothly and in an intuitive way, but also showed a high motivation to use the technology in the future. Their opinions were possibly influenced by the fact that the technology is meant to be directly accessible in their living room and individually tailored to their personal needs, allowing the individual to cope easier with their particular disease. Their intention to use such ambient technology is higher than in healthy and middle-aged persons. Also, according to the high average assessments of the perceived meaningfulness and fun, an overwhelming majority of the participants acknowledged the eHealth system was a useful, enriching, and sensible facility.

In addition, as the findings clearly demonstrated, it was advantageous to integrate serious games in the ambient technology systems. Although, it has also been shown that not every person in old age displays the same enthusiasm for gaming, technical aptitude, and self-efficacy, suggesting a great diversity of individual factors. This diversity among the users has to be considered whenever developing innovative healthcare solutions. Thus, engineers need to be adequately trained to understand and consider the users' diversity in this regard. Moreover, from the presented studies, it can be learned that basically all investigated user factors affected the attained performance in the game, however, age and the need for achievement were identified as the strongest predictors for the performance. This finding is in line with prior research (Fisk & Rogers, 1997; Fisk, Rogers, Charness, Czaja, & Sharit, 2009). From the users' evaluation, it was evident that the inclination towards gaming and gaming frequency are the strongest predictors for the intention to use the exercise game in the future. This finding seems obvious at first sight, but it is more deceptive under further scrutiny. On the one hand, exercise games are an excellent way to increase the fitness and overall health of the residents of technology-augmented home environments. They increase individual mobility and independence, and contribute to the idea of successful aging. On the other hand, according to the presented results these exercise games are much more likely to be used only by gamers. The nongamers are therefore at risk to be excluded from this motivating, entertaining, and preventive form of health-supporting intervention. Hence, future research should address alternative forms of technology-mediated exercising, for instance, by linking the creation of music or images with cognitive or physical exercises. Corresponding to the users' diversity, the different inhabitants of technology-augmented habitats have varying interests. Therefore, a multifaceted set of exercising applications with different connecting points (e.g., games, music, paintings) should be offered. Finally, the game affected the individual's perceived exertion levels, which indicates that the players were actually involved in the game and aimed at achieving a decent score. And, even more importantly, playing the game had a strong positive effect on the perceived levels of pain. The younger participants started at a low level of pain, permitting only little space for a further decrease. In contrast, the older test participants reported a significant amount of initial pain that decreased over the course of the game. This result should not suggest that exercise games can substitute any medical therapies. Instead, they might be a valuable addition. The theory of pain mechanisms (Melzack & Wall, 1965) is further backed by the present data. As a consequence, the medical therapy of a resident of a health-supporting home environment may include a game-based exercise component. As outlined at the beginning of “Study II: Serious exercise games in AAL” section, this form of entertaining distraction from the actual therapy leads then to a lower perceived pain, as well as increased fitness, mood, and overall well-being.

However, there are also some limitations that need to be considered for future research. The presented studies consider how smart health technology is perceived, and how it is intended to be used by the residents of technology-enhanced habitats. Obviously, this view into the future is tainted with uncertainty. On the one hand, the development of technology may follow different and currently unimagined paths. On the other hand, future elderly persons may have different perceptions of technology in general, and computer games in particular. It is evident that technology expertise is formed by individual upbringing and by the technology types that dominate each generation. It follows that technology experience might differ between the generations (Prensky, 2001; Sackmann & Winkler, 2013) and that there is a need to examine in how far different generations might get familiar with using such complex systems, adopting them as a natural part of their lives.

Another interesting line of research is to concentrate on gender effects. One reason for this is that women still have a higher average life expectancy and live longer than their husbands or partners. Thus, in the next decades, we can expect a superior number of women as senior users (Barford, Dorling, Davey Smith, & Shaw, 2006; Durndell & Haag, 2002). Besides, although slightly in contrast with the results presented in Study I (health-related context), there is a strong empirical evidence that women show a lower interest in technology and a higher level of anxiety when handling novel technologies. This goes hand-in-hand with a lower self-efficacy with digital devices, which makes women much more careful and reluctant to interact with technology (Durndell & Haag, 2002). From this point of view, the general use of smart ambient technologies might be a serious hurdle for this user group. However, regarding the use of social media, women show a higher emotional involvement and social engagement in digital communication in comparison to men (Sun, Wang, Shen, & Zhang, 2015). There is also a high social motivation to be friends with, and stay in contact with, family members or peers (Barker, 2009; Thelwall, Wilkinson, & Uppal, 2010; Woolham & Frisby, 2002). Thus, a high involvement in the use of social media could be a powerful motivational anchor or trigger point to attract women to use health-supporting applications at home.

In conclusion, the presented findings provide evidence for a basically motivated attitude towards, and a high intention to use, such technology solutions at home, especially of elderly and chronically diseased persons. According to the resulting high scores for fun and perceived meaningfulness, the combination of the entertaining games and the serious background gives reason to conclude that Maria, who is autonomously checking her relevant health parameters, might be able to enjoy her independence, as characterized by self-determination and dignity in life for longer, and also to improve her social network through the game-based interactions with her grandchildren.

Responsible research and innovation in technology development for older adults

A final thought of this chapter regards the claim for responsible research and the consideration of ethical, legal, and social implications of technology development. In times in which technology developments, fostered by the huge and tremendously fast evolving innovations through modern information and communication technologies, enter private spheres and come into close contact with individual, private, and intimate activities, it is a mandatory claim that any technology development should be carefully developed and balanced within societal, cultural and individual values and norms. Within the European Union, the term “responsible research and innovation (RRI)” was formed under the prospective EU Framework Programme for Research and Innovation “Horizon 2020” (Stahl, 2013; Stahl, Eden, & Jirotka, 2013; von Schomberg, 2013). The concept was recently introduced as across countries there is—beyond the market itself, which might dictate which product is successful in the end—no normative instance which might define best practices or might assess and evaluate consequences, responsibilities and impacts of technology for the countries, the society, and the users (von Schomberg, 2013). Stahl (2013) points out that RRI is a social concept “that is meant to mediate the consequences of technical and other innovations on our individual and social lives” (p. 202). In Germany, a similar movement can be observed. With the ELSI (ethical, legal, social implications) and the ELSA (ethical, legal and social aspects) the German Ministry for Education and Research fosters the consequent consideration of these aspects in all research projects in which technology development, education and social aspects for different stakeholder groups are under study. As the RRI concept and the ELSA/ELSI approach are currently quite normative, the individual’s rights and ethics when using technology should be the base for the ELSI perspective (Nelles et al., 2017; Owen, Macnaghten, & Stilgoe, 2012; Sutcliffe, 2011).

To come back to the issue of responsible research and technology development for older adults, we argue that any of these developments should comply with the claim for a socially responsible technology design. Beyond the normative aspect and the impact of RRI and ELSA concepts for policy, however, we strongly vote for including older adults in a bottom up process and asking for participation exactly those persons, for which these technologies are designed. It is important to keep in mind that smart homes and embedded health-supporting technologies have an enormous potential to bring forward and facilitate some crucial mechanisms regarding consequences of demographic change. And this is not only because the so-called eHealth technologies promise to deliver significant improvements in the access and quality, and to increase the efficiency of care as well as the productivity of the health sector (Holzinger, Dorner, Födinger, Calero Valdez, & Ziefle, 2010; Kleinberger, Becker, Ras, Holzinger, & Müller, 2007). It is much more a long-term success of smart health-technologies, depending on the sensitivity with which the users and their specific requirements, needs, values, as well as their culturally and individually formed wishes are considered during the development and implementation process.

To conclude, the responsibility in the research can be outlined on the basis of three major cornerstones of the age-appropriate technology developments: First is the *holistic and interdisciplinary technology development.* In contrast to the standard technology development currently practiced, in which mostly medical or technical facets are the center of attention, there is an urgent need to develop integrative models for the design of user-centered healthcare systems. The new concepts of health-monitoring systems within ambient living environments should be suited to support users individually (i.e., according to the users' profiles and specific needs), adaptively (i.e., in accordance with the age-related changes and/or depending on the course of disease), and sensitively (i.e., corresponding to the living conditions under all circumstances) (Blanchard-Fields, Hertzog, Stein, & Pak, 2001; Klack et al., 2011). A second important point is the *novel understanding of age and aging.* The technical development in the context of health-supporting ambient systems should be based on a sensitive concept of human needs and specifically tailored to the requirements of the most frequent user group: Seniors. This could mean that the devices and technical systems then unveil their reverse side: Smart health systems being not only compensatory for the negative effects of aging (e.g., general frailty, cognitive or physical deficiencies), but rather the complete opposite. The support of the positive aspects of aging like life-experience, domain knowledge, skills and expertise, wisdom, and fun in the old age should be deeply anchored as benchmarks in a sustainable technology development (Blanchard-Fields et al., 2001; Sackmann & Winkler, 2013). As such, technology development then has the responsibility to empower elderly people as an active part of the society (Ziefle & Schaar, 2014). Eventually, the third cornerstone refers to *integrating the users in the whole design process.* The most important modification to traditional technology development approaches in the field of medical engineering is to include the users actively during the whole process of the technology innovation (participative design). A coherent, user-centered design of health-supporting devices integrated in home environments will result in ambient technology which is not only functional in an engineering way of thinking, but it also addresses the users' fundamental needs in terms of unobtrusiveness (nonstigmatizing design), ease of use, perceived usefulness, and overall usability (Wilkowska, 2015). Especially in case of AAL and smart health systems, this is a vital precondition. For the majority of us, the home is the most intimate and conversant place, and technology that is integrated into this sensitive piece of one's identity must unconditionally adapt to the lifestyle and requirements of its inhabitant(s). Therefore, it is obvious—and should appropriately be acknowledged in both the research and in the industry—that involvement of the users as well as careful considering of their perspectives, wishes, and requirements into the technical development process prospect a reasonable chance of successful adoption and in the long run is able to bear the burden of a graying society.

Acknowledgments

This work has been funded by Excellence Initiative of Germany's Federal Ministry of Education and Research and the German Research Foundation.

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