Research Article

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Best Practices for Designing Electronic Healthcare Devices and Services for the Elderly

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Abstract: Demographic change and associated shifts in the age structure lead to major challenges in health processes. One way to address this is to increase the use of telemedicine systems and services to ensure non-local yet individualized patient care, such as in rural areas. When considering new medical technology components, we must compensate for age-related changes in perception, cognition and motor skills to achieve user-centered design and take into account psychophysical effect relationships to achieve sustainable acceptance for technology integration. This paper presents various best-practice examples for participatory investigation into influencing factors, with a focus on the different times and periods within the lifecycle of a telemedical product and associated services. In addition to giving concrete design hints derived from individual studies, the paper discusses the strengths and weaknesses of the paradigms used and provides recommendations for user-centric development with old and very old patients.

Keywords: Methods, Health, Age, Elderly, HCI, Information

1 Introduction

Electronic devices and human-computer interaction have found their way into everyday life, and they now play a role in many activities that used to be based on person-to-person interaction. Additionally, our society is aging rapidly so a growing user group of elderly people who are not digital natives or digital emigrants will have to interact with a growing number of digital devices. Beyond some restrictions in perception and cognition that often – but not generally – come with age, these users will also differ widely in terms of their experience with electronic systems and the concepts and mental models they have for the devices they are using.

This is particularly applicable for the integration of appropriate technical components in health processes because the large inter-individual differences in terms of health literacy, specific therapy requirements and actors involved as well as the impact of specific illnesses lead to extremely complex socio-technical systems. The use of mobile ICT systems for patients to independently monitor their own health has great potential to compensate for the expected results of demographic change by delinking medical care from local availability of medical staff. Here, telemedicine systems and services refer to the use of information technology and communication technologies within the provision of healthcare processes. By exchanging valid information for diagnosis, therapy and prevention of diseases and injuries, spatial and / or temporal distances between participants can be overcome to solve medical problems.

Usability and ergonomics in medical and telemedical applications is peculiar because such interaction is not always voluntarily. Instead, this interaction is driven by safety needs (such as after a heart attack) and prescribed by a doctor. In addition, monitoring equipment and assistance systems carry a certain stigma because they make the patient's medical needs obvious. In this context, patient acceptance of the product and adherence within the therapy context is particularly important, since their absence can cause direct lethal consequences. One must also consider the sometimes dramatic impact of disease incidents on the psyche and the somatics of the target group. As a result, the usual effect relationships used to model interaction and acceptance cannot be validly transferred.

The goal of this paper is to highlight best-practice examples for target group-oriented design of human interaction with medical and medical-technology products.

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Accordingly, it should be clear that depending on the specific question, non-generic approaches and time horizons (in terms of where in the product lifecycle, for how long and in what environment) have to be used during evaluation in order to validly reflect psychophysiological effect relationships:

- Qualitative / semi-structured interviews to determine requirements as well as reservations for application systems within a therapy before system development
- Laboratory studies looking at the specifics of human-machine interfaces, in particular for information input and output, that respect disease-specific changes in perceptual skills, motor skills and cognitive skills
- Field studies of initial experiences with specific products and services as well as within the first use phase, such as for prevention, therapy or rehabilitation
- Long-term studies for self-dependent use in everyday life to ensure sustainable use of potential for monitoring vital parameters, for example

To support a corresponding user-centered or patient-centered approach for elderly people within the design, development and evaluation of medical technology products and services, this paper gives examples for the use of the paradigms described above and briefly presents outcomes. In addition to giving a consolidated presentation of the results of the respective model studies, it also provides recommendations for the design of various experimental paradigms (especially for older subjects).

2 Methodological Approach and Exemplary Results

The ensuing methodological approaches are no review of the state of the art but best-practice examples for target group-oriented design of human interaction with medical services and medical-technology products relying on own research approaches.

2.1 Qualitative Interviews: Information Needs and Behavior

A deep understanding of user needs is crucial for building successful digital services and technology. At the beginning of research activities, it is important to understand and specify the user's context, goals and activities to achieve a high-quality use experience.

This is especially important for health-related systems with end users who have exceptional requirements: elderly people, for example, are less familiar with modern information and communication technology (ICT) and are also experiencing a decline in cognitive function [10, 13, 17, 20, 29]. Current context analysis therefore aims to investigate what information has a meaning for an elderly person's health. Knowing what a patient needs to know about their health and what sources they use to find that information creates a basis for designing and developing artifacts that convey health information to them. So it is important to know (1) how the elderly obtain relevant health information, (2) what health-related information they need, and (3) how and why they go to certain information sources.

Concerning information needs in healthcare, individual coping strategies have been shown to have an impact on information needs [15]. In addition, coping strategies as part of activation mechanisms, psychological, demographic, role, environmental and source characteristics have an impact on a person's information needs [2]. Activity theory [14, 16] and Wilson's model [26, 27] of information-seeking behavior lay the foundation for questions about health-related activities, required information and confounding variables.

2.1.1 Method

Qualitative interviews provide rich and detailed information for investigating the context of health information systems. At the beginning of each session, participants filled out a questionnaire about demographic and role-related parameters. Then they completed a semi-structured interview investigating health-related information needs and behavior. All interviews included detailed questions about health, personal health and related concepts (medication, prevention, health and vital data, health insurance, hospitals and institutions) and about activities, goals, and tools they use, share and access health information with. The interview template was based on existing interview guidelines on the information needs of urban residents [25]. Audio recordings from a Phillips DVT 4000 dictation machine were transcribed with T4 transcription software and inductively coded. The Ethics Committee at the RWTH Aachen Faculty of Medicine authorized this study and its ethical and legal implications with Statement EK179 / 15 in September 2015. The preliminary sample of $N = 10$ – to which the results of this paper refer – has a mean age of 75,2 years including a standard deviation of 7,829.

2.1.2 Results

Preliminary results for n = 10 showed that the information the elderly require to stay healthy most frequently consists of a diagnostic assessment of an observed symptom along with cause estimations and treatment recommendations (n = 9). Three participants reported that they were completely satisfied with the health information they get, while six participants reported that they were partly satisfied with the information available to them. Four participants described problems getting information about examination results and related procedures. For example, one woman reported that "*my family doctor told my gynecologist that a certain blood reading was too high during my pregnancy. Our family doctor informed me by phone on a Friday, but he was not able explain the consequences or the significance of that blood reading. So I started to panic while I was searching for information on the Web and talking to friends and family members over the weekend. The gynecologist provided me with the information I needed on Monday. They completely ignore their patient's situation sometimes.*" One male participant described a case where "*I did not receive the PSA results for a blood test my urologist took a week before. Trying to get information about the test outcomes by phone was impossible because of their privacy policy and the fact that the urologist was not available. So I had to wait until the next appointment. I think this is really inefficient and time-consuming.*" Six other participants also reported having trouble contacting their physicians. In addition, four participants described information-sharing between medical experts as cumbersome. One participant suggested "*a solution that documents the content of each appointment, diagnosis and treatment as patient history that could be shared between physicians and viewed or even edited by patients.*"

Last but not least, four participants described information needs regarding health insurance services. Details about pricing and availability of chargeable health services were considered insufficient, especially if covered by private health insurance. Four participants desired greater transparency regarding billed services versus performed services. One woman described lack of information to the effect that the trustworthiness of commercial healthcare actors often only becomes apparent with scrutiny. Sixty percent of the preliminary sample believed that an excessive preoccupation with health-related information could trigger a disease. As a result, they avoid devoting any more attention than necessary to health issues. "*Knowing everything about a disease does not help if you are suffering. Quite the opposite. My husband was a heart surgeon suffering from a deadly cardiac disease and he often said that he wished he*

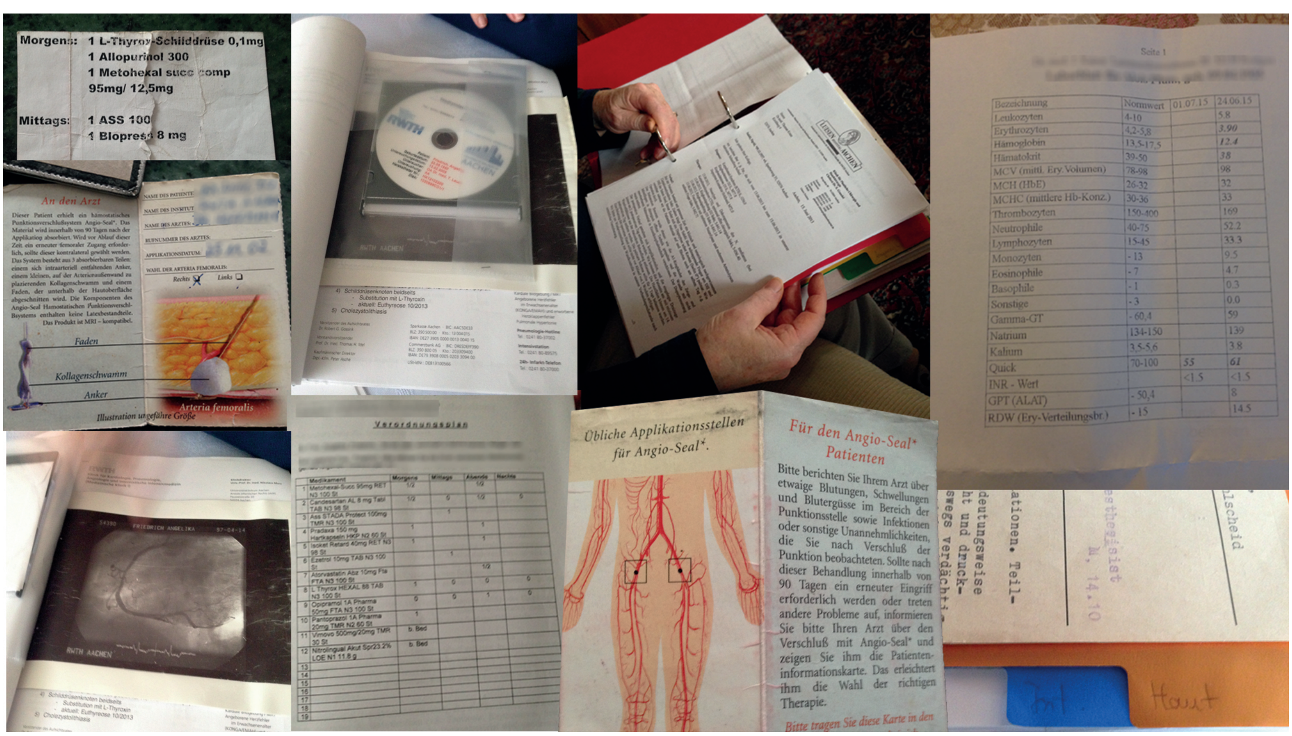

Figure 1: The exchange of health information between doctors and patients in Germany is still paper-based or conversation-based. The examples above encompass blood charts where critical items are marked in bold, procedure documentation is illustrated with images, medication reminders and complete documentation of a patient's medical history.

knew nothing about it," said one woman. Consequently, an information need could be described as having been adequately met if it only provides relevant information – and in some cases this might even imply excluding information. This woman's statement represents a common assumption that might have to be considered during the conceptualization and development of healthcare technology if the analysis of the entire sample suggests similar conclusions. This is because some health information and health information systems might emphasize a symptom or a disease. Assuming that some patients attempt to block out their illness as part of a coping strategy, health information and technology could lead to acceptance issues. In contrast to the 60 % group that believes an excessive preoccupation with health-related information could trigger a disease and so they avoided engaging in health information-seeking behavior, we identified a second group of 40 % that actively engages in health-related information behavior. They (1) put effort into quantifying and documenting personal health data in order to monitor their health, (2) strive to improve health-relevant behavior and (3) cooperatively use the data they gathered to communicate health-related information to stakeholders.

Elderly patients perceive their physician as a competent professional authority to whom they outsource information processes and decisions so as to not burden themselves with information searches and decision-making in addition to dealing with their disease. Participants rated their family doctor or a specialist as their most important health information source (n = 9)

2.2 Laboratory Study: Interactions on Touchscreens

Because of technological progresses the way of interacting with input devices in computing changed from being indirect as the motion of the devices had to be translated to the motion of a pointer on a screen and became more direct as touch technologies were introduced into the market. When using direct input devices like smartphones or tablet pcs the space directly surrounding the body called peripersonal space is crucial. Thereby, the representation of peripersonal space is dependent on the integration of multi-modal feedback. Yet very little is known about age-related differences in the representation of peripersonal space. Past studies of the influence of age on movement tasks have found that differences in hand motion are attributable to differences in the perception of peripersonal space, not to deficits in motor skills [11]. Based on studies administered by Tipper, Lortie and Baylis [22], which found that while executing grasping movements the position of the object is automatically encoded in reference to the hand in younger subjects, Bloesch et al. [5] showed that in older subjects the reference frame is not specifically attributed to the hand but to the body as a whole.

Research focusing on the position of the hands with regard to visual stimuli has recently received a great deal of attention. One of its main findings is that stimuli that are close to the hands are perceived and processed more precisely than those that are more distant. With regard to visual short term memory, for example, subjects are able to retain more items in memory when their hands are near a display than when their hands are further away from a display [23]. Another positive effect exists when a subject must process visual stimuli with regard to the detection of a specific target. The results of five experiments administered by Reed, Grubb and Steele [19] showed that subjects detected target items that appeared close to their hand more quickly than targets further away from their hand. Interestingly, the direction of the hand proximity effect varies with the task context, having a positive effect on performance in some tasks but a negative outcome in other tasks. On the negative side, for example, the effect of having hands nearby influences the rate of learning of visual material since learning is slowed down when the hands are near the stimulus [7]. Furthermore, the presence of hands decreases the ability to shift attention between items [1] and reduces the effectiveness and speed of semantic processing of sentences [8]. To study the hand proximity effect more closely, we did an age-differentiated analysis of an extensive visual search task and compared two different distances between the hand and the screen where the task was administered. In line with the literature we have cited, we hypothesized that search times would be longer for hands nearer to the screen versus hands further away from the screen, given that results from Abrams et al. [1] predicted a decrease in attentional disengagement.

2.2.1 Method

A total of 78 right-handed subjects with normal or corrected-to-normal vision participated in the study. Subjects were divided in two age groups by a median-split. The younger group ranged from 20 to 39 years of age (mean = 26.22, SD = 4.98), and the older group ranged from 40 to 74 (mean = 54.55, SD = 10.43).

Subjects were seated at a desk in front of a computer with a viewing distance of 500 mm from the screen. The two hand conditions are shown in Figure 2. In each condition, a computer mouse located under the subject's right hand served as an input device. In the first condition, both hands were placed at the sides of the display and the arms were supported by an elbow rest. In the second condition, the hands were placed on a wooden slat resting on the subject's lap. In both conditions, the horizontal distance between the hands was kept constant.

The search display consisted of a matrix containing 48 rectangles with different alphanumeric characters. Characters that look similar in upper case and lower case were presented only once. In total, each of the 48 rectangles needed to be searched in a random order for each hand position to ensure that every part of the display would be included in the task, resulting in 2 × 48 trials of the visual search task. During every trial, one character that needed to be searched was presented first. After that, a blank screen was shown as a masking stimulus for three seconds, followed by the search matrix in which alphanumeric characters were arranged randomly in every trial. At the beginning, instructions for the task were given and five practice trials were carried out per condition. After locating the search stimulus participants were instructed to click the mouse with the right index finger.

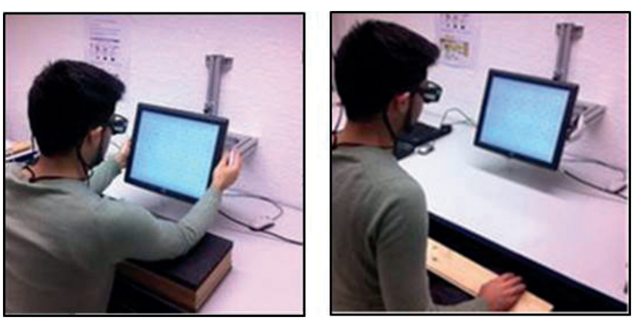

Figure 2: Visualization of the study conditions: Hands on the screen (left), hands on the table (center) and hands on the lap (right).

2.2.2 Results

In order to analyze the data of the study statistically, the Wilcoxon signed-rank test was used with hand position as an independent variable and search time as a dependent variable for the two age groups. Since we only had directional hypotheses, the p-valuewas calculated with a one-tailed test and was set to $\alpha = 0.05$.

The results show an effect for hand proximity depending on age. Search times were significantly longer for hands positioned at the screen ($M = 3441.42$) versus hands positioned on the lap ($M = 3228.14$) in the younger age group, $z = -1.85$, $p = .032$, $r = -0.19$. In the older group, search times were shorter for the position at the screen ($M = 4004.65$) versus the position on the lap ($M = 4009.52$), $z = -0.21$, $p = .84$, but not at a significant value. Figure 3 shows the 95 % confidence intervals for the corresponding values.

In summary, the effect found in this study is inversely related with participants' age. This implies a difference in peripersonal space between younger and older subjects that is in line with the cited literature [5, 11]. In a follow-up study, eye-tracking measures should be used to study the effect of proximal hands. Particular attention should be given to mean fixation duration, an indicator of the difficulty of extracting information from a display, and pupil dilation, which may indicate cognitive workload.

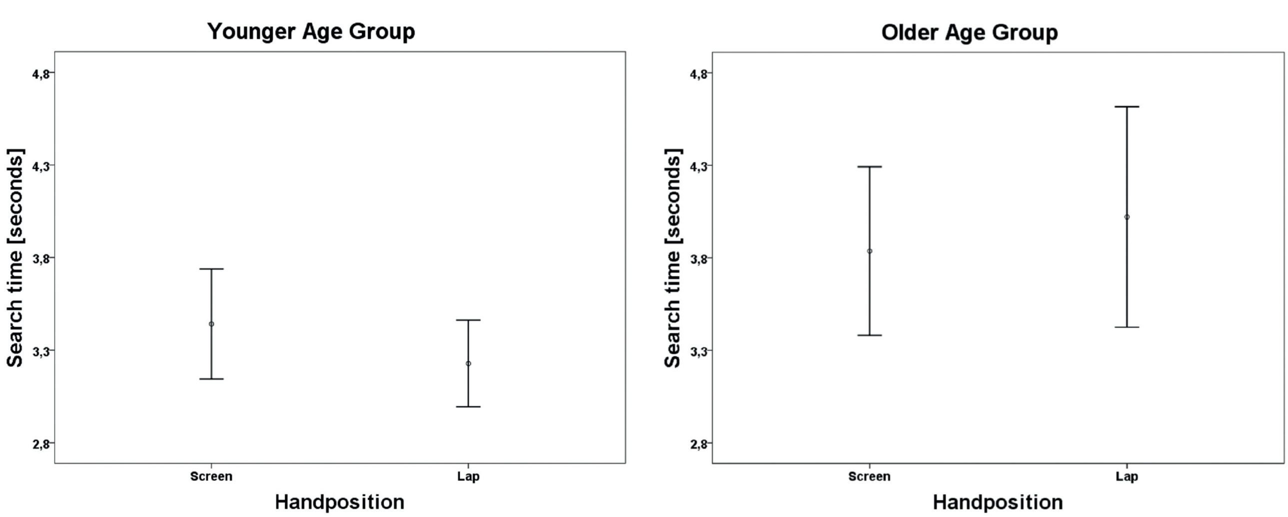

Figure 3: Error bar graphs of search times showing a 95 % confidence interval.

2.3 Field Study: Acceptance and use of Fitness Trackers

Daily physical activity and exercise has been shown to reduce the risk of mortality and age-related morbidity and to have a generally positive effect on older adults' (+ 65 years) physical and mental wellbeing, and so they are essential for healthy aging [24]. Although the World Health Organization (2010) promotes these effects [28], more than 70 % of older adults are not active enough [24]. A key reason for older people's lack of daily exercise is their lack of information about their individual capabilities and limitations [12]. Activity trackers are able to fill this need. They have also been shown to motivate young users to become more physically active [6, 21].

We performed a four-week field study to investigate age-related usability for an activity tracker and corresponding daily activity [18]. An activity tracker can measure and count steps as well as classify user movement during sleep. A corresponding app displays all recorded data for personal optimization or medical evaluation. The Ethics Committee at the RWTH Aachen Faculty of Medicine authorized this study and its ethical and legal implications with Statement EK038 / 15 in February 2015. Participants were recruited for the study subsequently.

2.3.1 Method

Each participant had three individual meetings (at the beginning, after two weeks, and four weeks after the study concluded) during which different metrics were gathered. During the initial meeting, the activity tracker was put into operation in line with defined usability tasks. These tasks employed a "think out loud" method and measured subjective mental workload with the Rating Scale of Mental Effort (RSME) [30]. Participants were then asked to use the activity tracker according their own personal preferences in the weeks that followed. Each participant had an activity goal of 10,000 steps a day as proposed by the WHO (World Health Organization) [28]. During the follow-up meetings, semi-structured interviews and a pairwise comparison were performed to identify positive and negative aspects of each activity tracker experience as well as to determine relevant aspects of activity trackers for young people and elderly people.

Two age groups ($x < 30$ years; $x > 60$ years) were compared to identify age-related differences. A total of 30 participants (14 female, 16 male) took part in the study, none of whom had any experience with activity trackers. The group of younger users comprised 15 participants (6 female, 9 male) recruited at RWTH Aachen University. The 15 older participants (8 female, 7 male) were recruited during a special technical lecture for elderly people at RWTH Aachen University. The age of the older participants ranged from 60 to 78 (mean age 68 years, SD = 5.29). The age range within the younger group of participants was 19 to 30 (mean age 25 years, SD = 2.59).

2.3.2 Results

All participants completed the full period of four weeks of activity tracker usage as validated by their recorded daily activity. Older participants reported the highest mental effort during the tasks "app installation," "charge" and "putting into operation." In the younger group of participants, only the "putting into operation" task was evaluated as requiring a high degree of mental effort. An ANOVA revealed that the mental effort for the tasks "app installation" and "charge" differed significantly due to the investigated age groups (app installation: $df = 1$, $F = 9.511$, $p = .007$; charge: $df = 1$, $F = 10.075$, $p = .006$).

According to the interviews, participants felt comfortable using an activity tracker and they were willing to use this kind of product in their everyday life. 14 out of 15 older participants reported during their last meeting that they would appreciate an activity tracker as therapy support because of motivational aspects (6 out of 14 participants) and objective control (10 out of 14 participants). 12 out of 15 in the group of younger participants reported this too, although they were unable to give detailed reasons for their decision. When asked whether they intend to use the tracker for the next 12 weeks, the elderly were more likely to say yes too. Measured on a seven-Likert-scale (1 = I totally agree, 7 = I totally disagree), the average answer for elderly participants was 2.57 (SD = 2.138). For younger participants, it was 3.87 (SD = 2.900).

The pairwise comparisons of the basic requirements that an activity tracker should fill showed that functional range and data accuracy were rated highest by the older group. Requirements like price and design were rated lowest. The group of younger participants evaluated functional range and comfort highest. They rated requirements like price and battery life lowest. The ANOVA revealed significant differences between the younger group and the elderly group for data accuracy ($df = 1$, $F = 7.383$, $p = .011$) and design ($df = 1$, $F = 6.201$, $p = .019$). No significant differences were found for the pairwise comparisons of different key functions that an activity tracker should have. We therefore performed a qualitative analysis. Elderly participants weighted the functions "measuring pulse"

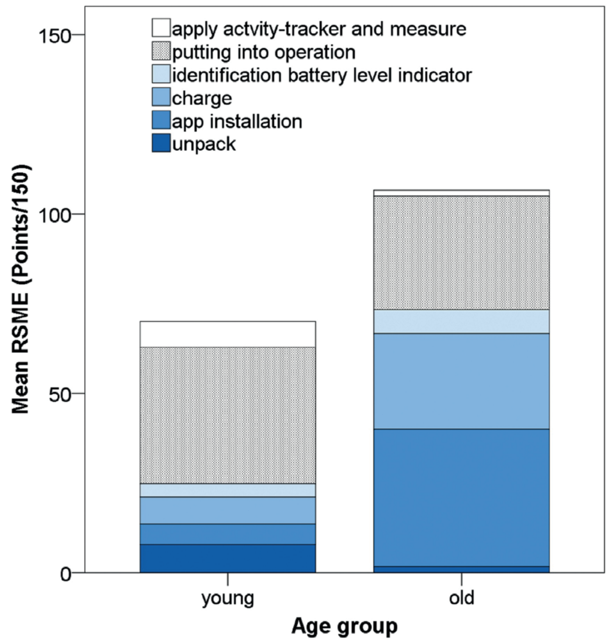

Figure 4: Sum of the RSME subjective strain ratings in different tasks for older and younger subjects.

and "counting steps" higher than the other available functions. Younger participants rated the functions "measuring distance" and "measuring sleep" highest.

The semi-structured interviews support the results of the pairwise comparisons. Participants said that they prefer to use the activity tracker instead of a wristwatch. Such a device should be waterproof so users can wear it in the shower or during swimming or aqua fitness. Both groups reported that the tracker should always display the time when specific data like number of steps or burned calories is not being accessed. In addition, participants reported that the tracker provided to them could only be worn on their left arm. If they wore it on their right arm, the data was displayed upside-down. A positive aspect reported by all participants was the tracker's long battery life. When fully charged, the tracker could measure their steps for up to seven days.

In summary, our results show activity trackers have a motivating effect, which supports the results obtained by Clemes et al. [6] and Steinert et al. [21] for younger users. Our research extends these results to the group of older users. Participants reported that they were motivated and that they appreciated the activity tracker as motivation and as an objective support during a therapy and daily life. All participants integrated the activity tracker into their daily life.

The results show that activity trackers are generally suitable for use by the elderly. All participants were able to use and put the activity tracker into operation without specific training or support from the investigator. Nevertheless, usability still had room for improvement. For instance, participants said the time should always appear on the tracker display so it could be used in place of a wristwatch. They also said people should be able to wear the activity tracker on either arm. A clip to attach the tracker to a waistband would be greatly appreciated to offer greater wearability, said users. Women in particular liked to wear the activity tracker in their pocket or even on their ankle, especially when they were wearing jewelry on their wrists. The results of the evaluated RSME numbers show that mental demand differs between the older participants and the younger participants. Elderly participants reported high mental effort for installing the app. The main reason reported for this high mental effort was a lack of training.

2.4 Long-term Study: Therapy Adherence

Self-management and therapy adherence are crucial factors for patient rehabilitation success after events like an myocardial infarction or apoplectic stroke, yet both are challenging when it comes to managing patients with chronic conditions. For the individual, non-adherence is associated with a number a safety issues such as increased risk of toxicity or more severe relapses [9]. Forgetfulness is very often stated as a reason for unintentional non-adherence. Novel strategies are therefore required to better address the needs of elderly and chronically ill patients and support therapy-compliant behavior [4]. Mobile information technology and associated software applications may offer new system solutions to better meet these needs, because such services are available everywhere, they can react in context-sensitive ways (day of the week, time, place, appointments, etc.) and the graphical user interface can be adapted to specific needs (font size, contrast, language, etc.).

We conducted a longitudinal study to arrive at valid conclusions about the influence of demographic factors like age, gender, educational background and individual medical history on the acceptance of a medication adherence tool in a representative German population subset. This has enabled us to identify constraints for self-reliant usage of such systems to effectively improve medical adherence and derive recommendations for promising target groups. The Ethics Committee of the Medical Faculty of Essen University was consulted and a formal written waiver for the need of ethics approval was issued (13-5373-BO).

2.4.1 Method

The mobile application "Medication Plan" was available as a free download from the Apple App Store from 2010 to 2013. It was designed to support the regular, correct intake of medication [3]. The native application allowed users to maintain and alter a drug therapy plan on a personal device like a smartphone or tablet computer (Figure 5). Users were able to specify intake requirements according to the medication regimen issued by the prescribing physician and the patient's own personal needs. A reminder function and local push-notification alerts reminded users to take their medications at the pre-specified time. Users could enter vital-sign data, and trends were presented graphically.

Before using the application, users had to give their consent to a disclaimer as well as an agreement permitting subsequent anonymous analysis of user data. Additionally, users were invited to voluntarily and anonymously complete an online questionnaire. The data, which was gathered from 2010 to 2013, was examined using a multi-factorial analysis of variance (ANOVA) with a significance level of 0.05. Dependent variables were "duration of longer usage" (defined as use of > 1 day; if no activity was recorded for > 10 days, this was rated as end of use) and "mean intensity of usage per day" during the period of active usage. A total of 1,708 complete data sets were recorded for users of the Medication Plan application (1225 male, 483 female; age 19–65).

2.4.2 Results

More than two-thirds of users (1,183 of 1,708) used Medication Plan for more than a day. Overall, men used the application significantly longer than women (χ^2 (1, N = 1761) = 6.715, p < 0.010). Looking at the different age cohorts, there was a significant correlation between age and "longer usage" (> 1 day) (χ^2 (5, N = 1799) = 15.255, p < 0.001). With increasing age, reliance on the application for more than 1 day rose from 50 % of those below 21 years of age to over 70 % for those 40 or older, yet the effect was stronger in men for all age cohorts (Figure 6).

The number of diseases for each user significantly affected duration of usage (χ^2 (5, N = 1799) = 12.144, p = 0.030). While the proportion of individuals who stopped using the application after one day was 42% for those who did not have to take any drugs, it was 25–30 % for those who were on regular medication. Similarly, the number of drugs significantly affected duration of usage (χ^2 (7, N = 1799) = 30.612, p < 0.001). This effect is not surprising because only a fraction of the available functions were still useful (such as keeping track of weight and vital parameters) for users with no medical conditions and no need to take drugs on a regular schedule. Variance analysis presented the following effects with respect to duration of usage: With a mean duration of usage of 23.3 days (SD 36.9) for users under 21, there was a substantial increase across all age cohorts, with users 60 and older

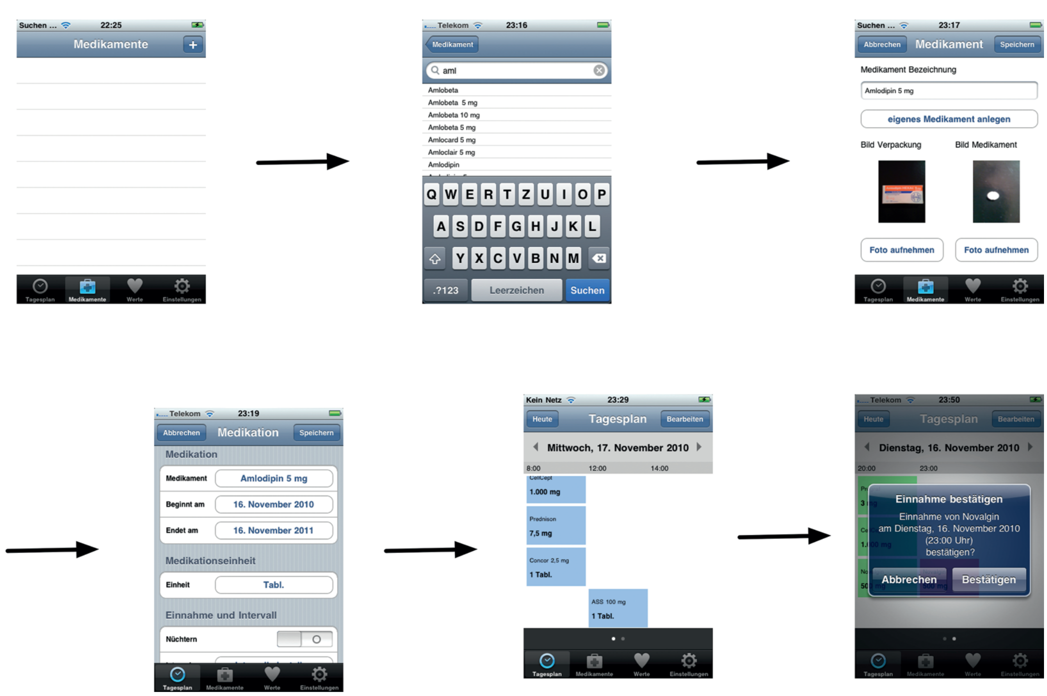

Figure 5: Generating a medication plan on a smartphone.

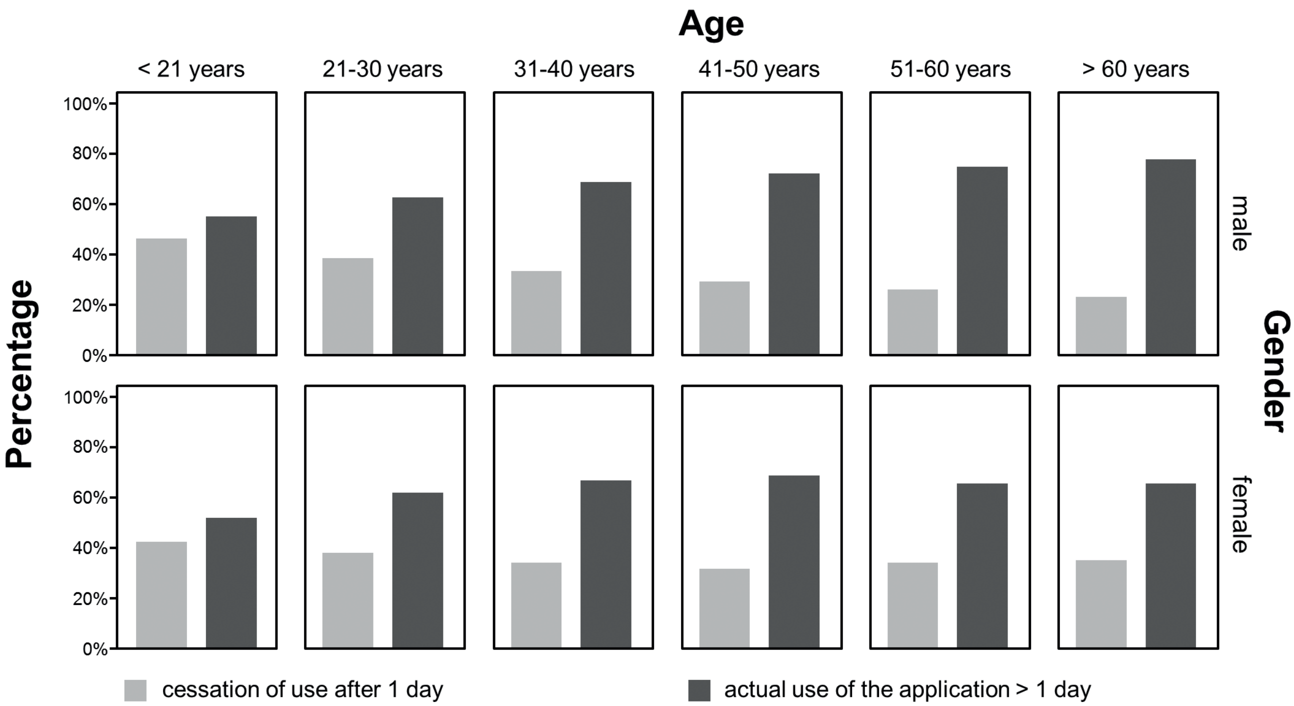

Figure 6: Distribution of user behavior by age and sex.

using the application for 103.9 days on average (SD 20.7) ($F = 2.581$; $df = 5$; $p = 0.025$). For users 50 and older, usage duration seemed to remain static. Post-hoc pairwise analysis with Bonferroni correction showed significant differences between all groups with a minimum age difference of 20 years. Mean duration of usage for users who did not abandon the application during the first day was 85.4 days (SD 138.6) (Figure 7).

Sex ($F = 1.084$; $df = 1$; $p = 0.298$) and educational achievement ($F = 0.656$; $df = 2$; $p = 0.519$) had no effect for those who did not stop using the application after one day. The number of medical conditions ($F = 0.403$; $df = 5$; $p = 0.847$) and the number of drugs taken per day on a regular schedule ($F = 0.967$; $df = 7$; $p = 0.259$) did not affect the duration of usage significantly. Interestingly, variance-analysis of individual medical conditions showed a significant effect on duration of usage if the user suffered from cardiovascular disease ($F = 14.098$; $df = 1$; $p < 0.001$) or had received a transplant ($F = 12.503$; $df = 1$; $p < 0.001$) (Figure 4). In either case, people with these diseases used the system on average about 50 % longer than people not suffering from the same condition. With regard to usage intensity, the number of diseases tended to affect usage intensity ($F = 1.974$; $df = 5$; $p = 0.080$). The number of regularly taken drugs had a significant impact on usage intensity ($F = 4.017$; $df = 7$; $p < 0.001$) and increased with the number of drugs taken per day.

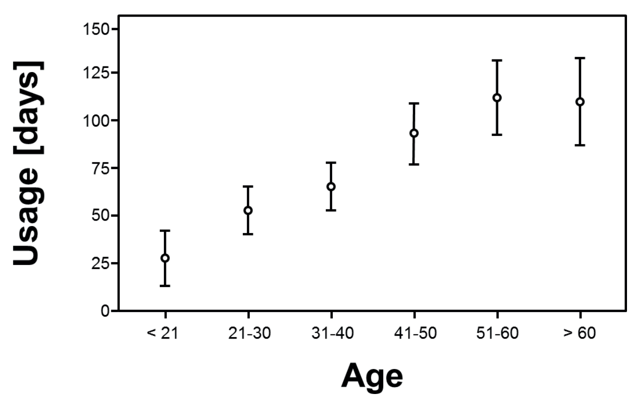

Figure 7: Mean usage duration for the age cohorts.

In summary, it can be said that use of the application for more than one day grew with age, yet the effect was greater in men across all age cohorts. Once a user decided to keep using the application, further factors (disease and associated medication) had an effect on usage duration and usage intensity.

3 General Discussion

When using medical systems and telemedical systems, the challenge is to consider the physical and psychological impact of a disease on the individual in addition to large inter-individual differences (especially for very old people, because the prevalence and incidence of chronic diseases significantly increases in old age). An autonomous and error-robust ICT is therefore highly important because direct negative consequences for the health of the user may result without one.

The studies point to an example of how experts can integrate users in different stages of the product lifecycle in order to ensure user-centric implementation. Here, in addition to concrete results, we gathered a wealth of experience for carrying out empirical studies with older persons. We have condensed that knowledge below in a generic form for use as best practice guidelines:

- Qualitative studies with the elderly have proven to be a valuable tool for gaining insight into user needs and contexts. Especially when investigating abstract concepts like information needs and behavior, it is useful to have researchers and participants interacting in a conversation. However, as each interview tends to be unique with no predetermined set of questions being asked of all respondents, it is usually more difficult to analyze unstructured interview data, especially when results need to be synthesized across respondents.
- Qualitative studies are also a great source for generating new ideas for telemedical systems that address the needs of end users. Design recommendations based on given qualitative studies, for example, include technical systems for digital natives growing old. Since they are used to digital communication systems, these users will expect communication with their physician to be digital.
- Laboratory studies can provide insight into concrete empirical data tested under steady conditions, and they can show effects that are small in size (milliseconds) but that have a large impact during continuous interaction with devices. However, laboratory studies are limited in ecological validity because they always take place in an artificial situation that does not reflect the scenarios in which the tools are used later.
- Field studies have higher ecological validity. This is especially important in the context of the elderly because it enables heterogeneous concepts and mental models of the elderly to be taken into account and gives subjects time and space to get involved with the product at their own pace. But since these situations are not properly controlled, hidden influences from surroundings might not be detected or might influence results. So it is useful to use this type of study in an exploratory setting.
- Long-term studies are needed, because only long-term use of appropriate tools allows researchers to validly map the influence on everyday life and the capability of supporting adherent behavior patterns. This way, researchers can consider learning effects that come from interacting with appropriate ICT systems, fears that frequently occur at the beginning and strong initial motivation toward self-guided use.
- It is important to mix ecological validity and controlled conditions to identify sufficiently valid but sufficiently specific conclusions for existing interactions, which can then be used to ensure the success of individual therapy and a target group's use of ICT.
- Research with older people takes time, because they deal with products intensely before and after purchase, and because they expect this approach in studies too.
- Elderly subjects expect the benefits of a study to be communicated clearly. They are only willing to participate once this condition is met.
- Elderly subjects must be ensured that their opinion is highly valued. They need to be convinced that every person's opinion is important, regardless of age.

Complex socio-technical systems, as demonstrated by the example of telemedicine systems, require research that integrates information, data, methods, tools and theories from more than one domain. Our experience shows that socio-technical systems are a great field of application where the strength of interdisciplinary research reveals its full potential. By mixing all these different ways of thinking about methodological approaches, this kind of research can stimulate effective solutions that no group or field has created before.

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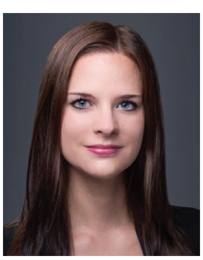

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