Attitudes of Elderly People towards Assistive System: Influence of Amortization Barriers on the Adherence in Technically Assisted Rehabilitation and the Diffusion of Health Technologies

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Due to the current demographic change the demand for comprehensive care concepts for elderly is increasing. The numbers of incidence and prevalence of diseases and consequential disabilities are constantly rising. Integration of assistive technologies and services in healthcare processes represent a promising possibility to tackle care related challenges in an effective and sustainable way. A barely researched obstacle to human-machine interaction, especially to elderly users of assistive systems, was detected during an earlier clinical trial. This obstacle is called amortization barriers and describes the effect of users not having the need to buy a new device before not fully exploiting all functions of the current. The associated negative effect on adherence is described by qualitative and quantitative data. Additionally concrete advice for compensation is derived.

Practitioner Summary: The influence of amortization barriers on the adherence of elderly patients needs to be considered when prescribing telemedical systems as part of a medical therapy.

Keywords: Telemedicine, Adherence, Demographic Change, Human-Machine Interaction, Human Factors Engineering

1 Motivation

Due to demographic change the need for comprehensive care concepts for elderly is constantly rising. The population is not only aging but with this the incidence and prevalence rates for age related diseases and disorders which reduce quality of life for affected individuals (Böhm et al., 2009). The integration of assisting technologies and services in health care represents an extremely promising possibility to encounter the shift of age patterns and its challenges with an effective and sustainable approach (Ansorge et al., 2012). Although many pilot studies show positive effects with regard to effectiveness of telemedicine for different diseases as well as reduction in total costs, e.g. in Germany the usage of telemedical systems in health care for example is not yet comprehensive. Besides organizational and legal conditions serving as obstacles for technology diffusion, the insufficient consideration of human factors and therefore the lack of acceptance through elderly user, prevent the sustainable and effective establishment of telemedicine (Schaar & Ziefle, 2010).

1.1 „Amortization Barriers“

During a clinical study with 20 elderly cardiological patients an obstacle known from marketing research was identified in the context of human-machine interaction especially for elderly users of technical assistance systems. This obstacle is known as ‘amortization barrier’ (Averesch, 2012) and describes the effect that some users have the demand to fully utilize the potential of a technical device before purchasing or using another, especially if they are not using all features of the device or if they are satisfied with the features and have no need for improvement (Heinz et al., 2013) (Tacken et al., 2005). This comprehensible effect, in terms of marketing when introducing innovative products, also occurred among the study participants. That is why the influence on adherence of the participants needs to be considered as part of the therapy when prescribing telemedical systems. Participants monitoring their vital parameters regularly in a paper diary, e.g. with help of a sphygmomanometer to measure their blood pressure, often do not see the added value by digital documentation of the data using a telemonitoring system. Therefore their compliance was significantly lower compared to participants with the same technical affinity having not monitored their vital parameters independently preliminary to the study.
2 Methods

2.1 Study design

The clinical study is based on a cross-over experimental design over four weeks. For the purpose of this study a four level experimental design was developed and consisted for all participants of the following steps:

1) Introduction to the study including baseline medical examination and prospective recording of attitudes towards technology.
2) Two level coaching program in order to practice the handling of the telemonitoring system at the hospital and later at home.
3) Four weeks autonomous use of the telemonitoring system in consultation with the treating cardiologist. Telematic monitoring of vital parameters through the doctor in charge of the study. A medical as well as technical support service via phone was available work days from 8 am to 6 pm.
4) Completion of the study including measurement of vital parameter through the doctor in charge. Recording attitudes towards technology after the four week program and a structured interview.

Through integrated recording of all patients' interaction processes with the telemonitoring system, the subjective collection of adherence data could be avoided since patients tend to overrate their adherence in this method and data often is not sufficient (Wang et al., 2004; Cook et al. 2003). The retrospective analysis of usage patterns in terms of usage duration and -frequency was executed automatically after completion of the study based on the internal protocol. Thereby, precise and valid findings concerning the actual user behavior were possible.

2.2 Hypotheses

With regard to influence of attitudes towards technology on adherence during autonomous usage of telemonitoring systems, following research hypotheses and corresponding null hypotheses were developed:

H₁: A positive attitudes towards technology is accompanied by a higher usage frequency.
H₂: The higher the usage duration, the more positive is the attitudes towards technology.
H₃: Positive attitudes towards technology increases regulation conformity.
H₄: Attitudes towards technology is increased by interaction with telemonitoring systems.
H₅: Usage frequency increases during autonomous usage of a Telemonitoring system.
H₆: The longer the time period of autonomous interaction with a telemonitoring system, the more increases the regulation conformity.
H₇: Usage duration increases during autonomous usage of a telemonitoring system.

2.3 Experimental variables

The attitudes towards technology were captured at different points in time during the study: Before the actual usage of a telemonitoring system and after completion of the study as repeated measurement inner subject factor. A target group specific questionnaire based on TA-EG Questionnaire (Karrer et al., 2009) and a questionnaire by Gina & Sherry (1992) was used for this purpose and classified the participants. The participants were clustered according to rather negative attitudes (attitudes < 2), neutral attitudes (2 ≤ attitudes ≤ 3), and rather positive attitudes (attitudes > 3). As further dependent variables, the usage duration per meeting and the absolute usage frequency, recorded automatically within the protocol, was collected. The regulation conformity gives the percentage of conducted measures pursuant to the agreed treatment.

2.4 Task

The medical guideline according to the telemonitoring system was to use it on a daily basis on an individual prescribed time slot, based on individual living circumstances, of one hour in the morning and in the evening.
On this occasion relevant measures for cardiologic diseases (blood pressure, heart frequency, electrocardiogram (ECG), weight and physical activity) were carried out using microsystems technology sensors and questions concerning well-being and medical intake were answered. Additional measurements could be taken outside the defined time slots when required. Autonomous control of all measured parameters was possible due to visualized health trend.

2.5 Equipment

The Telemonitoring system available to the participants consists of several modular elements coupled via Bluetooth. The so called ‘homebox’ is a mobile Toughbook by Panasonic (CF-H1) which disposes a 10.4” dual-touch display and can be positioned upright in its base station (operating system Windows XP). The luminance of 500cd/m² provides a much brighter screen than usual touchscreens to be clearly legible in day light. Additionally the legibility was improved through optical and mechanical antireflexion coating for usage in bright surroundings. The screen is the central interface from the user perspective, on which all interaction processes happen. The usage of the touchscreen only happens with fingers on a graphic user interface designed for this purpose. The system reminds the user in the defined time slot visually through continuous blinking on the front screen and acoustically through a singular sound for 30 seconds of required measurements. The elements to measure vital parameters are a personal scale by Beurer, provided with Bluetooth (BS 9930 BT) by Corscience. Blood pressure was measured with Boso-Medicus prestige, also provided with Bluetooth, and was suitable for independent use due a specific arm cuff. Physical activity and ECG was measured with the BioHarness chest band by Zephyr, which makes it possible to collect biomechanical activity measures via 3D-accelometer or to collect electrocardiogram and heart frequency with textile electrodes on the skin. All used sensors were examined with regard to manageability and autonomous usability through elder users and were finally considered as suitable.

2.6 Participants

In total 20 participants took part in the study, while only 17 were able to complete the study successfully and were considered during analysis (mean age: 76.4 years; SD = 6.7). Two participants dropped out due to health problems and one participant had to be withdrawn due to the occurrence of technical problems during data transfer. The participants were distributed in 9 women and 8 men. To be included in the study the participants must have experienced a myocardial infarction or another acute cardiologic disorder in the past three months and are currently treatment for these disorders. 35.5 % of all participants reported vocational training as their highest degree of education, followed by participants with vocational extension certificates (29.5 %). Participants with an academic background or a secondary school degree were represented with 17.6 % In total the participants were equally distributed among the different age groups with regard to gender and highest education. Referring to their former occupation, 29.4 % reported to have worked in the craft sector, 23.5 % worked within the technical/science sector and 11.8 % worked within the commercial business/administrative and social science/humanities sector. Housewives/husbands were represented with 23.5%. All participants were retired at the beginning of the study, whereas 70.6 % were retired for over five years at this point. The majority of the participants (47.2 %) are currently living in an own house or in an own flat. While 35.2 % pay rent and 17.6 % are living in an assisted living senior residence. 35.2 % reported to live with their spouse or in direct contact with other family members. 29.4 % of the participants are living alone. In total 64.7 % came across computer or computer based systems in their private life or during occupation. However, 52.9 % reported to use computer in their private environment.

3 Results

17 participants were able to complete the study successfully. The classification of the participants beforehand, based on their attitudes towards technology, resulted in six participants having a relatively negative attitudes towards technology, six participants having neutral attitudes, and five people having relatively positive attitudes towards technology. The criteria for inferential statistical analyses of the dependent variables were all met.
3.1 Relationship between attitudes towards technology and usage behavior

Due to the data concerning the usage frequency and duration collected during the clinical trial, it is possible to analyze the user behavior retrospective with regard to adherence and to match with the tasks prescribed by the physician. The measurement points per day, defined in the task, resulted in a minimum of 56 interactions with the system within the 4 weeks of usage based on a hundred percent treatment adherence. The usage duration arose from the timespan that was necessary to perform the different measures and to answer the corresponding questions. No guidelines were set for this purpose. The analysis of the protocol files with regard to these two factors is visualized in Figure 1.

Figure 1. Usage frequency and usage duration of the telemonitoring system during the study in percent.

The average usage frequency (MV = 58.4, SD = 6.6) shows a relatively small distribution of less than 10% of the mean, while the usage duration (MV = 26.3, SD = 17.6) showed a greater distribution of two third of the mean. This shows a relatively high and homogenous willingness for cooperation, while efficiency and effectivity during interaction must be evaluated as relatively heterogeneous. The regulation conformity (MV = 83.0%, SD = 7.1) is appraised as high compared to other studies (Merkel, 2011). A differentiated analysis with regard to the influence of the three factor levels of attitudes towards technology before the study (see Figure 2) revealed a significant influence on the usage frequency (F = 4.20; df = 2; p = 0.03), as well as usage duration (F = 6.61; df = 2; p = 0.01) with a small or medium effect size of $\omega^2 = 0.09$ and $\omega^2 = 0.05$. The corresponding null hypotheses to $H_{01}$ and $H_{02}$ were rejected.

Figure 2. Usage frequencies during the study period, average usage duration per session and regulation conformity in dependence on the attitudes towards technology.

The analysis of the influence of the attitudes towards technology on regulation conformity also shows significant differences (F = 7.14; df = 2; p < 0.01). The paired t-test revealed that all three factor levels are significantly different (for all statistical tests apply significance levels of 95% with $p < 0.05$). $H_3$ can be accepted through the rejection of the corresponding null hypothesis. The analysis of the relation between the previous described variables shows significant correlations (see Table 1). Thereby it is remarkable that the attitudes towards technology have a significant negative correlation with usage duration ($r = -0.63$)

The identified relation is highly contrary, meaning the higher the usage duration, the less positive are the attitudes towards technology. Interestingly a negative correlation between usage duration and frequency ($r = 0.23$) and regulation conformity ($r = 0.31$) creates the effect that a higher usage duration is accompanied by a lower usage frequency and low cooperation in medical treatment.
Table 1. Correlations between dependent variables and attitudes towards technology.

<table>
<thead>
<tr>
<th></th>
<th>Attitudes Towards Technology</th>
<th>Usage Duration</th>
<th>Usage Frequency</th>
<th>Regulation Conformity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitudes Towards Technology</td>
<td>1</td>
<td>-0.63**</td>
<td>0.43**</td>
<td>0.52**</td>
</tr>
<tr>
<td>Usage Duration</td>
<td>-0.63**</td>
<td>1</td>
<td>-0.23*</td>
<td>-0.31**</td>
</tr>
<tr>
<td>Usage Frequency</td>
<td>0.43**</td>
<td>-0.23*</td>
<td>1</td>
<td>0.92**</td>
</tr>
<tr>
<td>Regulation Conformity</td>
<td>0.52**</td>
<td>-0.31**</td>
<td>0.92**</td>
<td>1</td>
</tr>
</tbody>
</table>

* The correlation is significant at a level of 0.05
** The correlation is significant at a level of 0.01

In order to identify the direction of the effect, the different event logs as well as screen shots were examined with regard to the above average usage duration of single participants. Insufficient understanding of the interaction processes, e.g. touching of greyed out keys and waiting for a system response, were identified as primary reason in most of the cases. For one participant technical problems during connection with the measurement sensor were the reason as this caused necessary measurement repeating and timing confusions within the system waiting for data input based on implemented time restriction before continuation of the process.

This implies that an insufficient efficiency and effectivity during human-computer interaction of single participants led to a significant increase of the usage duration and not the ‘fun’ during usage. Therefore the user’s willingness to use the assistive system, expressed in usage frequency and regulation conformity of the interaction, as well as the attitudes towards technology was negatively influenced. This explanation is based on results from prior user studies which proofed that a lack of previous experience has a strong negative effect on attitude towards technology (Mertens, 2015).

The significant correlation between attitudes and usage frequency (r = 0.43) was to be expected since a positive attitude towards technology is reflected by positive acceptance in terms of active willingness to usage (Brandl et al., 2013).

As the most relevant result for this study, in terms of influence of attitudes towards technology on adherence, the significant correlation between attitudes towards technology and regulation conformity (r = 0.52) need to be evaluated. Although an explicit statement concerning the question which factor is “actuator” and which factor is “sensor” for this interdependency is not possible, it is assumed that positive attitudes towards technology increase regulation conformity and therefore directly adherence. This is based on the different phases of acceptance formation during interaction with technical systems (Brandl et al., 2012).

### 3.2 Changes in attitudes towards technology

In the course of this study for long term use, it is possible to evaluate not only short term effects with regard to between subject factors, but also the influence of a long term, continuous interaction with a telemedical system.

The analysis of the influence of the four-week interaction with the telemonitoring system on the attitudes towards technology was based on a paired t-test. A differentiated analysis for all three factor levels of the attitudes towards technology before the study reveals a significant change of attitude (p < 0.01) from MV = 1.73, SD = 0.33 to MV = 2.45, SD = 0.56. For participants with neutral attitudes towards technology is the change less significant (p = 0.08) and changes from MV = 2.37, SD = 0.63 before participation to MV = 2.75, SD = 0.59 after a four week usage. For participants with positive attitude a minimal, non-significant improvement (p = 0.23) was detected from MV = 3.29, SD = 0.43 to average attitudes towards technology MV = 3.43, SD = 0.48. As participants with initial negative attitudes towards technology experienced a significant positive influence through system usage, thus hypothesis H4 can be accepted due to rejection of the corresponding null hypothesis.

Due to the detailed logging of the telemonitoring system it is possible to analyze timely changes of usage frequency and duration as well as regulation conformity on a daily basis (see Figure 3). The analysis shows only a small increase of average usage frequency over the time period with a non-significant effect (F = 11.30; df = 27; p = 0.19). Therefore the null hypothesis corresponding to H5 cannot be rejected.
For regulation conformity, defined as ratio between agreed usage and actual usage there is also no significant effect present over the study duration (F = 9.90; df = 27; p = 0.23). Thus, the formulated null hypothesis corresponding to H₆ cannot be rejected. A significant change with an effect size of ω² = 0.18 with regard to usage duration can be identified (F = 10.11; df = 27; p = 0.03) explained by reduced usage duration during increasing usage period. The corresponding null hypothesis to H₇ can therefore be rejected. These results correspond to the analyzed time effects for the attitudes towards technology and the correlation between the dependent variables. The tendency to an increasing positive attitude towards technology motivates for adherent usage. However, usage duration as well as regulation conformity were reduced through learning effects during system usage. A differentiated analysis of changes of usage frequency over the total study period, for all three factor levels of attitude towards technology, using a paired t-test result in significant differences between participants with a more negative attitude and participants with a neutral attitude (p = 0.02) as well as a more positive attitude (p < 0.01). The comparison of the two last-mentioned groups reveals no significance (p = 0.34). It is determined that changes are rapidly increasing during the first two weeks for persons with a more negative attitude towards technology (Δ = 0.5 and Δ = 0.3) and after three weeks a relatively constant level is reached (Δ = 0.1). For participants with neutral or relatively positive attitude towards technology only small variations appeared within the usage frequency during the total study period and a slight increased tendency can be observed (Δ = 0.3 and Δ = 0.2).

It can be concluded that the less positive the attitude towards technology at the starting point, the higher perceptible the overall positive effect of interaction with a telemonitoring system on usage frequency. This effect discovers saturation after about three weeks. It has been proven that regulation conformity increased continuously during the study period independently from the total attitudes towards technology. Thereby significant differences between participants with relatively negative attitudes and participants with neutral attitudes towards technology (p < 0.01) exist according to usage frequency. A significant difference was also found between participants with relatively negative and positive attitudes towards technology (p < 0.01). Between participants with neutral and a relatively positive attitudes towards technology no significant difference was found (p = 0.25). Likewise seen at usage frequency, a congruent development is emerging. Participants with relatively negative attitudes towards technology show the greatest changes during the first two weeks, whereas the increase of regulation conformity dropped in the second half of the study. Striking, in contrast to usage frequency, is that for all participants regulation conformity increased significantly during the last week compared to the third week (negative: p = 0.01; neutral: p = 0.01; positive: p < 0.01). This phenomenon appears independently from the participants’ attitudes towards technology. This could be explained by the foreseeable end of participation and the associated confrontation with the own cooperation with respect to the agreed treatment during the study (Schechner, 2013; Hattie & Timperley, 2007). This non quantified relationship could have been strengthened by the fact that the participants were contacted by their physicians via phone in order to arrange a final meeting. The paired t-test between factor levels of attitudes towards technology demonstrates significant differences in in the average usage duration over the entire study period (for all comparisons applies p < 0.05). The average usage duration is reduced by 47 % for participants with relatively negative attitudes towards technology, whereas usage duration is reduced by 21 % for participants with neutral attitudes and only 14% for participants with relatively positive attitudes towards technology. All three factor levels have in common that the most valid changes happened during the first two weeks. However, during the second half of the study period only marginal changes were recorded.
4 Discussion

Contrary to common studies about technical feasibility, medical effectiveness or usability of telemonitoring systems, this study focuses on the influence of attitudes towards technology on adherence. Due to the fact that elderly users were exposed to the system under real circumstances in their home by a long-term exploration phase the subjective perception allows drawing reliable conclusions. To ensure adequate supervision through attending physicians before the study and during the whole study period the sample size was relatively small with 20 persons participating. The quality of medical supervision was at least equivalent to standard care without usage of telematics systems.

A high validity with regard to the determined relations between attitudes towards technology and user behavior within the target group was guaranteed due to the fact that all participants experienced a myocardial infarction or another cardiological incident within the last three month before the study. Therefore the determined data within the study are based on realistic life circumstances, including the participants’ psychological state strongly influenced by the exceptional situation (Stierle & Hartmann, 2013). Thus the results allow giving reliable and directly transferrable recommendations in similar application cases, which would not have been possible with laboratory testing or with ‘healthy’ participants.

The used evaluation methods to record interaction processes were announced to the participants before the study by means of a participant’s information. However, this had little influence on the authenticity of the collected data due the non-noticeable integration in the system. Through the primary quantitative analysis with consideration to specific, qualitative aspects, arising questions regarding direction of interdependency for identified effects could be answered retrospectively. In the course of these analyses an obstacle known from marketing research, but not in the field of human-machine interaction, especially for elderly users of technical systems was proven. This obstacle is called ‘amortization barrier’ (Averesch, 2012) and describes the effect of a user wanting to fully use a device and not having the demand to buy a new device when not all functions are used fully or the existing functions are sufficient for their use (Heinz et al., 2013; Tacken et al., 2005). This comprehensible problem in terms of marketing during introduction of new products also occurred in case of the users within the study. Therefore this influence on adherence needs to be taken into consideration e.g. during prescription of telemonitoring systems. Participants who already measured vital parameters (e.g. blood pressure with a customary sphygmomanometer) on a regular basis and documented the results handwritten, experienced such a low added value through digital documentation. With regard to attitudes towards technology their usage frequency remained under average. During structured interviews at the end of the study this motivation was expressed by various participants in varying degrees. This allows the conclusion that the benefit, appearing during a regulation conform usage of a specific system (e.g. access to the data in real time through the attending physician) was not communicated sufficiently to the participants and the influence on adherence was underestimated. Especially for elderly users, integration of technical systems in their daily life as an end in itself is not expedient but needs to follow a strict objective target. With regard to the elicitation relation it has been proven that adherence could be influenced positively as well as negatively by the attitudes towards technology.

However, behavior is not only determined by the status quo previous to the first interaction with a telemonitoring system as attitudes towards technology change due to confrontation with system related characteristics and therefore can be consciously directed. A prospective planning and individual design of the initial contact associated operating instructions and supervision based on influences on personal profile factors, ascertainment during the first study, is both necessary and expedient in terms of the desired accordance of user behavior and prescribed therapy.

4.1 Derived recommendations

Following concrete recommendations were derived from the study in order to increase acceptance and adherence of elderly at usage of assistive systems:

(1) For persons with an increased personal risk for necessity of assistive technologies, interaction with technical systems should be fostered and motivated at an early stage e.g. for appointment arrangement or to get access to added value services.

(2) Before application of assistive systems it should be evaluated to what extend the future user disposes parts of the functional range e.g. through self-purchased products and is able to integrate
them respectively to describe the added value of the new system elements from the user’s perspective.

(3) Descriptions of support systems e.g. based on medical prescription should not advertise the multitude of possibilities and functions, but provide concrete improvements in comparison to the individual status quo.

(4) The first two weeks of autonomous use are crucial for successful integration of the technical system in individual living circumstances and therefore for long-term usage. Thus active support and success monitoring should take place during this time.

(5) Especially high aged persons with little previous experience in using technical systems represent a special risk group around the statistical average in terms of technology acceptance. Therefore they should receive proactive and short-cycle support.

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