USABILITY PROBLEMS IN A HOME TELEMEDICINE SYSTEM

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Abstract: Home telemedicine systems have the potential to reduce health care costs and improve the quality of life for many patients, including those suffering from chronic illness. This requires that the systems have functionality that fulfils relevant needs. Yet it also requires that the systems have a high level of usability in order to enable their users to employ the required functionality, especially if the target user group is elderly people. This paper reports from a usability evaluation of a home telemedicine system. Five elderly persons carried out specified tasks with the system, and based on that we identified usability problems with the system. The problems are presented, analysed in relation to 12 different usability themes and related to results from other evaluations of similar systems.

1 INTRODUCTION

There is growing interest in devices for home telemedicine. At world level, the life expectancy will increase from 2005 to 2050 to 67 years, and in developing countries to 76.5 years (UN, 2006). This has considerable consequences for healthcare budgets. Another key challenge is that the number of people with chronic illness is increasing and, due to frequent checkups at hospitals, these patients face reduced quality of life, as they have limited freedom to perform their daily activities.

The aim of home telemedicine is to reduce health care costs and at the same time increase the quality of life for patients. Home telemedicine systems allow patients to conduct measurements from their own home (e.g. glucose measurements for diabetes patients) and send the results to the hospital. Other systems put even more emphasis on self-management by supporting patients to take care of their own treatment. If home telemedicine systems are successful, they will reduce the workload of medical staff at the hospitals and in the patients' home, and relieve the patients from visits to the hospital or even hospitalization (Kaufman et al., 2003).

For home telemedicine systems to be successful, they must be safe and provide the required functionality. Many researchers have inquired into these aspects. Unfortunately, there are numerous examples of systems that fail despite having the right functionality, because the prospective users cannot use the system for its intended purpose. A problematic or incomprehensible user interface is a typical source of such problems.

Usability is a measure of the extent to which prospective users are able to apply a system in their activities (Rubin, 1994). A low level of usability means that users cannot work out how to use a system, no matter how elaborate its functionality is (Nielsen, 1993).

The potential of home telemedicine systems can only be realized if the systems have a high level of usability. Thus a high level of usability is a prerequisite for achieving savings on the healthcare costs and a better quality of life for the patients through use of home telemedicine systems. A high level of usability is particularly important when the main user group is elderly people, who may be constrained by motor, perceptual, cognitive and general health limitations (Fisk and Rogers, 2002) and, in addition, may have a low level of computer literacy.

1.1 Usability Evaluation of Health Care Systems

A number of research activities have studied home telemedicine systems and frameworks that aid in reducing the societal and individual costs of chronically ill elderly. The focus here has been on the functionality that is required from such systems. Examples are technology for ubiquitous biological monitoring using mobile phones, wearable sensory

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devices, multi modal platforms, framework and architectural descriptions and literature reviews of observed medical effects (Eikerling, et al., 2009; Fensli and Boisen, 2008; Jaana and Paré, 2006; Pascual et al., 2008; Sasaki et al., 2009; Sashima et al., 2008; Souidene et al., 2009; Taleb et al., 2009). The target user group of these systems is primarily elderly people.

Kaufman et al. (2003) conducted a case study where a home telemedicine system for elderly diabetes patients was evaluated through interviews, cognitive walkthrough and field usability testing. The evaluated system featured video conferencing, transmission of glucose and blood pressure readings, email, online representation of clinical data and access to educational materials. The study focuses on a methodology for conducting usability evaluation. It also provides a basic overview of barriers such as individual competencies, system usability issues and contextual variables. Two user examples of these barriers are provided.

A significant number of studies deal with health care systems where the target user group is professional medical staff. This includes evaluation of the usability of desktop, mobile and other healthcare systems with the aim of reducing medical errors introduced by technology. Examples are systems designed for supporting handheld prescription writing, decision support, ordering of lab tests, patient records, family history tracking etc. (Ginsburg, 2004; Johnson et al., 2004; Kushniruk et al., 1996; Kushniruk and Patel, 2004; Kushniruk et al., 2005; Linder et al., 2006; Peleg et al., 2009; Peute and Jaspers, 2007).

The research results presented here represent significant work on the needed functionality of home telemedicine systems as well as on methods for evaluating the usability of such systems. There is also considerable work on usability problems experienced with systems that are targeted at the medical staff. Yet much less efforts have been devoted to identification of usability problems in systems targeted at patients.

1.2 Objective

In this paper, we present a study where we evaluated the usability of a home telemedicine system targeted at elderly people. The aim was to better understand key usability problems that such users experienced when using home telemedicine systems. A better understanding of these problems is vitally important for future design of home telemedicine systems with a high level of usability.

In the following we describe the home telemedicine system and the usability evaluation we conducted with a group of elderly people (section 2). Section 3 presents the results with focus on key usability problems experienced by the users with this specific system. In section 4, we discuss these usability problems in relation to results found in other studies in order to emphasize more general problems for home telemedicine systems targeted at patients. Finally, section 5 provides the conclusion.

2 METHOD

In this section, we describe our usability evaluation of the home telemedicine system.

2.1 Usability Evaluation

System. The system was a telemedicine system intended for home use by elderly people to monitor their health. It included a Health Care System device (HCS) for data collection and transmission with a display, a speaker and four buttons for interaction, see Figure 1. As the manufacturer of the HCS wishes to remain anonymous we do not provide a reference to the system evaluated.

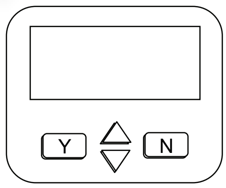

Figure 1: Sketch of the data collection and transmission device (HCS) of the evaluated healthcare system.

With secondary devices such as blood pressure meter, blood sugar meter and scales, users are able to conduct measurements at home and transfer these to the HCS via Bluetooth, an infrared link or a serial cable. At regular intervals, the device also asks the patients various pre-programmed questions regarding their health.

The system automatically transfers collected data to a health care center, where a nurse, doctor or other person is monitoring the health for a group of elderly patients. The system is sent to the patients in a package with a manual.

Setting. The tests were conducted in a usability laboratory, see Figure 2. In Subject room 1, a test participant was sitting at the table operating the system. The test monitor was sitting next to the participant, see Figure 3. Two data loggers and a technician who controlled cameras and microphones were in the control room during all tests.

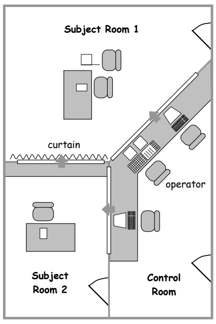

Figure 2: The setting in the usability laboratory.

Participants. The system was evaluated with 4 male and 1 female users. It should be noted that in the area of Human Computer Interaction it is customary to conduct formative usability evaluations using 5 test participants as this, from a cost/benefit point of view, is the most feasible. This number is based on studies conducted by Nielsen and Landauer (1993) showing that by using 5 test participants evaluators are able to identify 85 % of the total number of usability problems.

Since the system primarily is intended for use by elderly people, we selected test subjects ranging from 61 to 78 years of age. None of them had previous experience with this or any similar system. Their experience in using electronic equipment in general varied; two were novices, two were slightly experienced and the last was experienced.

Table 1: Task assignments used in the usability tests.

Task #	Task
1	Connect and install the HCS and secondary devices.
2	Transfer the data from the blood sugar meter to the HCS. The blood sugar meter is connected using a cable.
3	Measure the weight and transfer the data from the scale to the HCS.
4	A new wireless blood sugar meter is used. Transfer the data from this to the HCS.
5	Clean the equipment.

Six usability evaluators were involved, all graduate students specializing in human-computer interaction and working on their master thesis. They were all experienced in conducting usability evaluations. None of them had worked with health care systems before, and none of them knew the product in advance. In the evaluation, one of them served as test monitor in all five tests, and two served as loggers.

Procedure. Before the test started, the test participants were asked to fill in a questionnaire with demographic information. The test monitor then introduced the system and evaluation procedure. This included an introduction to the think-aloud protocol. The tasks were given to the test subjects one at a time. The test monitor's job was primarily to ensure that the test participants were thinking aloud and give them advice if they got completely stuck in a task. There were five tasks, see Table 1.

Data Collection. All test sessions were recorded using video cameras and a microphone. The videos showed the HCS screen and a small picture in picture with the user's face, see Figure 3. We recorded a total of four hours of video. Two loggers made written log files during the tests.

Figure 3: A test participant and the test monitor. The picture is from the video recording. The small picture in the upper right hand corner shows the interaction.

Data Analysis. The data analysis was carried out separately applying two different analysis methods: Video Based Analysis (VBA) and Instant Data Analysis (IDA), see the following two subsections. The purpose of using two methods was to get as rich and extensive a problem list as possible. Each team employed the procedure described below.

The problem lists from the VBA and IDA analysis were merged into a total list of identified usability problems. The test monitor and the data logger from IDA and the three evaluators from VBA did this. Disagreements were discussed until consensus was reached. In cases where the VBA and IDA lists did not have the same categorization for a particular problem, the proper categorization was discussed until agreement was reached. In this process, some problems were split into more detailed problems or merged with other problems.

2.2 Video-based Analysis (VBA)

The Video-Based Analysis was conducted in accordance with Rubin (1994). The three evaluators analysed the video material individually and made a list of identified usability problems. The severity of each problem was also categorised as either “critical”, “serious” or “cosmetic” (Molich, 2000).

The three lists of usability problems were discussed in the team and merged into one list of VBA problems. When there was disagreement or doubt whether problems should be combined or split, or how they should be categorized, the video material was reviewed and discussed until agreement was reached. This included agreement about the test subjects who experienced each problem. To measure the evaluator effect, we calculated the any-two agreement. The result was 40.2%, which is well above the minimum of 6% and close to the 42% maximum found in other studies (Hertzum and Jacobsen, 2003).

2.3 Instant Data Analysis (IDA)

The test monitor, one of the data loggers and a facilitator, who did not observe the tests, conducted this analysis immediately after all test sessions were completed. The analysis was conducted according to the IDA method (Kjeldskov et al., 2004).

The IDA analysis involved three steps: brainstorm, task review and note review. During these steps, the facilitator noted and organized all usability problems on the whiteboard as they were identified by the test monitor and the logger. After completing the third step, the problems were categorized as “critical”, “serious” or “cosmetic” with the same definition as in the VBA analysis. Finally, the test monitor and logger left, and the facilitator wrote up the list of usability problems from the notes on the whiteboard. The list was validated and corrected by the test monitor and data logger the following day.

3 RESULTS

This section describes the usability problems we identified in the evaluation of the HCS device.

3.1 Task Completion Time and Rate

Table 2 provides an overview of the time it took participants to complete each task. A grey cell indicates that a particular participant was unable to solve this task on his/her own and therefore received significant help from the test monitor; this is referred to as task completion rate. All users spent more time completing task 1 (connection and installation) compared to any other task, and 4 out of the 5 users could not complete this task without help.

Table 2: Task completion time and completion rate.

	Task					
User	**1**	**2**	**3**	**4**	**5**	**Total**
1	33:25	10:10	08:47	07:37	01:15	1:01:14
2	33:44	09:34	04:30	04:54	01:00	53:42
3	28:25	02:26	02:45	05:08	01:24	40:08
4	18:43	02:43	04:24	04:07	01:19	31:16
5	26:05	01:06	03:31	04:45	00:41	36:08
Average	28:09	05:12	05:35	05:18	01:08	45:22

There are noticeable differences between the time each participants spent on completing the other four tasks. For task 2, the time varies between 1 and 10 minutes. If a user is facing problems, it is very difficult to recover. For tasks 3, there is almost a similar variation. For tasks 4 and 5, there is very little variation. Tasks 2 and 4 are the same except that task 2 is with a wired device, while task 4 is with a wireless device. The difference may be due to the wireless connection, however there may also be a learning effect from task 2 to 4.

3.2 Identified Usability Problems

Table 3 shows the number of critical, serious and cosmetic problems identified using the VBA and IDA evaluation methods. By merging the VBA and IDA problem lists we identified a total of 51 usability problems.

Table 3: Number of identified usability problems.

	VBA	IDA	Total
Critical	14	15	14
Serious	15	13	15
Cosmetic	18	7	20
Total	47	35	51

3.3 Usability Themes

To get a better understanding of the different types of usability problems, we have categorized them in terms of 12 different usability themes. Below, we briefly explain the meaning of each theme based on Nielsen et al. (2006).

Affordance relates to issues on the users perception versus the actual properties of an object or interface.

Cognitive load regards the cognitive efforts necessary to use the system.

Consistency concerns the consistency in labels, icons, layout, wording, commands etc. on the different screens.

Ergonomics covers issues related to the physical properties of interaction.

Feedback regards the manner in which the interface relays information back to the user on an action that has been done and notifications about system events.

Information covers the understandability and amount of information presented by the interface at a given moment.

Interaction styles concerns the design strategy and determines the structure of interactive resources in the interface.

Mapping is about the way in which controls and displays correlate to natural mappings and should ideally mimic physical analogies and cultural standards.

Navigation regards the way in which the users navigate from screen to screen in the interface.

Task flow relates to the order of steps in which tasks ought to be conducted.

User's mental model covers problems where the interactive model, developed by the user during system use, does not correlate with the actual model applied in the interface.

Visibility regards the ease with which users are able to perceive the available interactive resources at a given time.

3.4 Distribution of Identified Problems

Table 4 shows the total number of identified usability problems distributed on usability themes and severity ratings. This shows that the users experienced problems from almost all categories, except cognitive load and interaction style.

The highest numbers of problems relate to information and user's mental model which account for 17 and 10 problems respectively. Collectively these themes include 53 % of all identified usability problems of which 7 are critical, 11 serious and 9 cosmetic. The remaining 10 problems (20 %) relate to the themes affordance (4), consistency (1), ergonomics (2), mapping (1), navigation (1) and task flow (1).

One of the problems related to the information theme concerned the user manual, which illustrates two possible ways of connecting the HCS to the phone line. In the manual layout, the illustrations were placed on opposite sides of an A5 brochure, which some of the participants interpreted as a sequence of steps. This resulted in some participants trying to connect the device like in the first picture and afterwards connecting the HCS as described by the second illustration.

A problem related to the user's mental model was identified during connection of the Bluetooth scale where participants were looking for a cable to connect this to the HCS, thereby exhibiting that they did not know how to connect these two devices.

14 problems relate to the themes feedback and visibility (7 in each theme) and account for 27 % of the total number of problems. 4 of these problems are critical, 3 serious and 7 cosmetic.

One of the problems with missing feedback was identified when participants had answered all of the pre-programmed questions. When the questions were completed, the display showed the idle screen with the company logo and did not provide feedback to the users of whether they were finished or not. This resulted in some of the users looking for a way to finish and others thought they needed to answer more questions.

A visibility related issue concerned the volume buttons on the HCS. A participant wanted to manipulate the volume and could not find the button, and therefore he tried pressing all other buttons on the device ("Y", "N", up and down) but with no result.

Table 4: Total number of identified problems distributed according to usability themes and severity.

	Critical	Serious	Cosmetic	Total
Affordance		2	2	4
Cognitive load				
Consistency		1		1
Ergonomics			2	2
Feedback	1	3	3	7
Information	5	8	4	17
Interaction style				
Mapping	1			1
Navigation	1			1
Task flow	1			1
User's mental model	2	3	5	10
Visibility	3		4	7
Total	14	15	20	51

3.5 Connection and Installation

As illustrated in Table 2 above, the task completion times and completion rates indicate that connection and installation of the HCS (task 1) was particularly tedious and problematic.

Table 5 shows the distribution of usability problems on themes, but only for task 1. Thus it represents a subset of the numbers in Table 4. This illustrates that 32 of the 51 problems (63 %) were identified during connection and installation of the device (task 1). Almost all critical and serious problems were found during this task where 11 usability problems out of a total of 14 (79 %) are critical, 12 out of 15 (80 %) serious and 9 out of 20 (45 %) cosmetic.

Table 5: Identified problems related to task 1: connecting and installing the device.

	Critical	Serious	Cosmetic	Total
Affordance		1	1	2
Cognitive load				
Consistency				
Ergonomics			1	1
Feedback	1	1	1	3
Information	3	8	4	15
Interaction style				
Mapping	1			1
Navigation	1			1
Task flow				
User's mental model	2	2	2	6
Visibility	3			3
Total	11	12	9	32

For this task, most problems also relate to information and user's mental model. The 15 problems with information contain all serious and cosmetic instances and 3 of the total of 5 critical problems were observed in task 1. When considering the 6 problems related to the user's mental model, we found that all critical (2) and almost all serious problems (2 of 3) were encountered in task 1.

The rest of the 11 problems identified in task 1 were distributed on affordance (2), ergonomics (1), feedback (3), mapping (1), navigation (1) and visibility (3). It is worth noting that all critical problems relating to these themes were observed in task 1.

As an example of an information-related problem in task 1, most of the participants did not understand the text "Detecting phone line" displayed during setup. This resulted in several participants lifting the nearby phone receiver and pressing various buttons on the HCS.

Another example regarding information was the term "Line", which was represented on the back of the device and in the manual, but it made no sense to the participants.

One of the problems regarding the user's mental model was when the users, in order to install the HCS, had to connect a cable from the phone line in the wall to the correct port on the HCS device in order to communicate with the remote server. However, the participants did not know which cable to use and some mistakenly tried to connect the phone and the HCS.

Another problem concerning the user's mental model was identified when the system asked the user to input a phone line prefix to bypass local in-building phone numbers. In our case, the users needed to press "0" as prefix in order to make the HCS able to communicate with a server outside the building. This prefix had to be selected on the HCS, but some participants pressed "0" on the phone with no result.

3.6 Qualitative Interviews

As part of the usability evaluation, we conducted a post-test interview with each user. The users emphasized that they "felt there were too many devices and cords that needed to be connected before the HCS was operational". It was also stated that the printed manual should be "redesigned and include more and better illustrations like the ones known from Lego and Ikea manuals".

Comments about technical lingo emphasized that words like "Detecting" and "Initializing" were unknown to the participants. Some also expressed that they needed more system feedback on what to do;, one of the participants said: "When the device does this and that, I need further instructions on how to respond". The missing feature to enable the user to undo an action was commented by some of the participants; one stated that "I pressed the wrong button when setting the date, but I was unable to go back and correct the error".

The interviews also revealed issues not identified during data analysis of usability problems. Most participants noted that they received no information about when and how the HCS was sending results to the hospital or care center. They were unsure whether the results were sent automatically or not.

The fonts on the display were perceived as clear and easy to read, however, some participants expressed that the soft menus (menus placed in the bottom area of the display mapping to the "Y" and "N" buttons, see Figure 1) where hard to read. This was caused by the relatively steep edge connecting the plastic cover and the display. The participants felt that they had to move closer to the device when reading the soft menu texts.

On the positive side all participants said that the HCS had good potential. Some expressed "Once the system is connected it would be easy to use". They would all prefer to use this type of device compared to hospital visits.

4 DISCUSSION

In this section we discuss our findings in relation to other studies with usability evaluation of health care systems.

We have found one previous evaluation of a system for use by patients. This is Kaufman et al. (2003) who asked their users to solve the following tasks using a home telemedicine unit (HTU): Measure glucose level, make blood pressure readings, access an educational website, send an email and change the calendar. These tasks differ partly from our study, but there is an overlap in the blood glucose reading task. Although most tasks differed, we identified some similar problems. They identified problems related to unnecessarily complex tasks, which can be compared to the problems we found during connection and installation of the HCS. Their study also revealed problems concerning non-transparent screen transitions, which are comparable to our problems with missing feedback. We experienced system crashes and restarts that frustrated several participants, and they noted issues regarding system instability. Information-related problems were experienced both in their study, where the users did not understand the blood pressure expression “212/89” referring to the systolic and diastolic values, and in our study the users also experienced such problems, e.g. they did understand the terms “initializing” and “detecting”. Mapping problems were also found in both studies. Their users could not establish a correspondence between a set of numbers presented one way on the blood pressure meter and another way in the PC application. In our case the users could not establish a connection between illustrations in the manual and the actual layout of the physical system. Finally, both studies identified issues related to the user’s mental model and visibility.

Kaufman et al. (2003) conducted a nonverbal analysis through comprehensive microanalysis, which provided further evidence on participant experiences. As noted in the paper, nonverbal analysis is especially useful in situations where indexicality is challenging, e.g. where the users lack a clear vocabulary when referencing interface objects like “scroll bar”, “drop down menu”, “check box”, “radio button” etc. This type of microanalysis is important in order to cover as many usability problems as possible. Yet it is also extremely time consuming and expensive, which is acknowledged by the authors.

There is a number of studies that focus on usability evaluation of systems designed for use by medical staff (Kushniruk et al., 1996; Kushniruk and Patel, 2004; Kushniruk et al., 2005). In these studies, the usability problems they have identified are distributed over a set of usability themes with various levels of abstraction ranging from information content, procedure (task flow), comprehension of graphics and text (user’s mental model) and overall system understandability to data entry and printing. The results from these studies confirm that information-related problems were observed in all of these. However, the percentage of information-related problems differs considerably from our study, where it is considerably higher. In Kushniruk et al. (2005) 16% of the identified problems are information related, while the number is 7% in Kushniruk and Patel (2004) and Kushniruk et al. (1996) (these are based on the same experiment). In our results, 33% of the identified problems were information related. For problems regarding the user’s mental model (comprehension) Kushniruk et al. (1996) observed 5% in this category. In our study this was 20%, thus we observed a relatively higher amount of this type of usability problem. In Kushniruk et al. (2005) and Kushniruk et al. (1996) the researchers found task flow related problems (procedure/operation sequence to be 15% and 6% respectively. Our study showed a lower percentage of 2% regarding task flow issues. The majority of issues identified in Kushniruk et al. (2005) were visibility related with a higher percentage of 26% compared to the 14% in our study. Thus, considering usability themes from systems designed for medical professionals, we identified a relatively high number of information related problems. This is also the case for problems concerning the user’s mental model. On the other hand we observed a relatively low number of task flow and visibility related issues.

5 CONCLUSIONS

In this paper, we have presented results from a usability evaluation of a home telemedicine system. The purpose of this was to emphasize key problems that designers of such systems should be aware of.

We identified the major usability problems to be within these five categories: Difficult to connect and install the system, the information provided is difficult to understand, the system does not conform to the user’s mental model, the feedback is insufficient and the resources of the system are not visible to the user.

This result is restricted in the sense that it is based on a usability evaluation of a single system with five users. However, we have compared our results to the limited number of related research results. We found a single evaluation of a system targeted at patients, like the one we have evaluated, and there are a few evaluations of systems targeted at medical staff. Both types of evaluations confirm the key problems we have identified.

This study has uncovered a surprisingly high number of usability problems given that the system has a fairly simple functionality. It would be interesting to conduct usability evaluations of other systems targeted at patients, in particular of more complex systems. It seems like the challenges for designers of home telemedicine systems are significant.

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