Usability Evaluation of Clinician Web Back-Ends to Telemonitoring Systems: Two Case-Studies in Scotland

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Abstract: One of the reasons why large scale deployment of telemedicine has not been successful is the difficulty healthcare workers have in managing the software. Good usability is essential to the success of a telemedicine solution. By ensuring that user needs are efficiently and effectively respected, usability encourages user acceptance and reduces the need for support. However, little is known about what healthcare workers require from telemedicine systems in terms of how patient acquired data is displayed and interrogated. This paper describes the results of a post-implementation investigation of the clinician web 'back-ends' of two telemedicine systems used for the monitoring of long-term conditions in Lothian, Scotland, focusing on the features healthcare workers would like to see in future systems. We conducted semi-structured interviews and questionnaires to ascertain the views of healthcare workers who had been using the systems. The results of the evaluation were used to design a new prototype generic telemonitoring website which we offered to participants to demonstrate possible improvements and to further seek their views. The prototype was very well received, participants considering that it was easier to use and more user friendly than the system that they had been using.

Keywords: telemedicine, usability, long-term conditions, telemonitoring websites, qualitative research, case-study, thematic analysis.

1. Introduction

In a recent review of conference papers exploring factors which influence the implementation of telemedicine, Broens et al concluded that technical and behavioural (i.e. related to acceptance) barriers are the most important factors determining the success of a telemedicine system [1]. In particular, they point to software **usability** both as a technical barrier, as it is related to the usefulness to end users, and behaviour barrier, as it influences the overall acceptance of a system.

The most commonly quoted definition of usability is that provided by the ISO 9241-11 standard: "*The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use*" [2]. A software system with good usability takes into consideration the users' profile, work context and respects the users' tasks. Good usability reduces the time and effort users need in their initial interaction and in the long-term use of the system, rendering interaction with the system easy and pleasurable. Usability has been shown to have positive influence on productivity [3]. By ensuring that the processes are intuitive to the users, it reduces the need for training and support and decreases error rates, as users learn to use the system just by trying it out. Despite the recognized importance of usability, developers do not appear to prioritise it in the design of telemedicine systems, concentrating on functionality [4].

Central to usability engineering is **user-centred design**. It involves end-users in the design of a system so that user requirements are better understood and respected by the system and, importantly, that users feel some ownership of the system, a process which has been shown to increase the system's level of acceptance [5]. However, end-users are often not sufficiently engaged in the design of healthcare solutions because of the commercial focus on building systems within short time frames [6]. This results in top-down designs in which usability problems are only observed after the rollout, when they are more costly to amend and often lead to the rejection of the system by its users.

We aimed to understand which aspect of 'back end design' caused most problems for healthcare workers and to determine what changes might enhance the user experience. To do this we carried out a post-implementation usability evaluation of two telemonitoring websites used in Lothian, Scotland, that had taken part in the Telescot programme of telehealthcare trials [7]. This programme evaluated the use of telehealthcare in a range of

long-term conditions. We then fed back the results of the evaluation to participants for their comments. Additionally we created, demonstrated and sought comments on a prototype of an improved generic website which incorporated suggestions from clinicians.

2. The Investigated Systems

The two telemonitoring websites we examined varied greatly, which allowed us to investigate a broad range of usability issues. The first, the IEM website [8], was developed by a German company. In our study it was used for the management of hypertension, a relatively stable condition, in a relatively well population which only requires weekly monitoring by nurses. Nurses or general practitioners (GPs) evaluated patient readings and contacted the patients by phone or email if the results were abnormal or if they had not sent in readings. Changes in therapy could be recommended remotely or if necessary patients could be asked to make a face-to-face appointment.

The second investigated website, provided by Intel Health Care ([9]) as an off-the-shelf solution worldwide, was being used in Lothian for the management of potentially unstable conditions- coronary heart failure (CHF) and chronic-obstructive pulmonary disease (COPD), in relatively unwell patients who required daily monitoring. The primary users of this website were monitors – some of whom were clinicians (nurses, respiratory physiotherapists and GPs) and some specially trained non-clinical staff who checked the patients' readings and answers to health-related questionnaires daily and contacted the patient to confirm abnormal readings and concerning questionnaire answers. GPs looking after the patients were contacted by the non-clinical monitors if an agreed symptom score was exceeded or a physiological measure (e.g. blood pressure, weight or pulse oximetry) was outside agreed parameters, whereas clinical monitors would contact patients directly. A representation of the monitoring process for the two websites is provided in Figure 1.

The two systems had been chosen by Telescot ([7]) because they contained relevant functionality for the purpose of the telehealthcare trial. Future users had not been involved in this choice or in any prior evaluation of the systems. Medical practices and hospitals from across Lothian had been involved gradually in the trial, leading to an array of user experience on the systems varying from between a few months and a year for IEM and a couple of months and two years for Intel. Users of the two systems had different workloads in terms of the number of monitored patients depending on the number of patients their practice had recruited for the medical trial (4IEM, 1-30 patients for Intel). The IEM system was used weekly by nurses and intermittently by GPs. The Intel system was used daily during weekdays by monitors and intermittently by GPs. Users had been trained informally on the systems by research nurses as part of the telehealthcare trial.

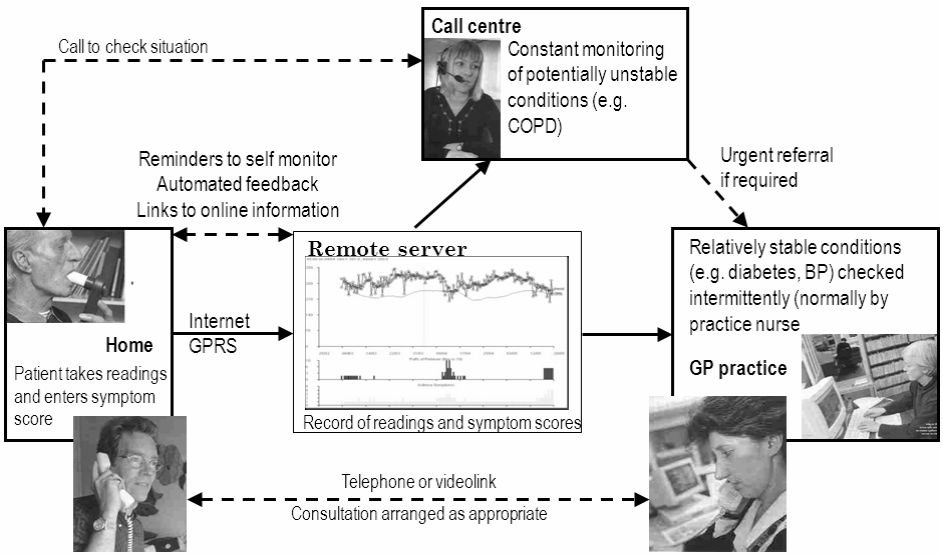

Figure 1. The monitoring process for the two telemonitoring websites, Telescot [7]

3. Methods

We adopted a mixed methods approach. We recognised that professionals are busy and often it can be hard to arrange meetings with them. We sought to interview them individually, face-to-face or by telephone, using a semi-structured 30-minute interview and the websites as a prompt, but if that was not possible we asked each participant to complete an on-line questionnaire instead. The questionnaire contained the most important questions from the interview, designed as open-ended or closed and intended to take about 20 minutes to complete. Both interview schedules and questionnaires were designed based on the usability literature ([2], [10], [11]).

We approached all the clinicians and non-clinical monitors who had been involved in patient monitoring in the Telescot telehealthcare trials ([7]) to participate. Interviews were carried out by this paper's first author, Cristina Alexandru, in association with Jenny Ure, the main qualitative researcher with the Telescot group. Interviews were digitally recorded and transcribed. Additionally, field notes were made of observations of participant reactions and, if appropriate, how the participant navigated the computer screen. All the participants gave written consent about participating to the study before the interview. Most of the interviews were carried out in the participants' office, which also gave us the opportunity to make observations of their work environment and work habits.

Data was analysed by Cristina Alexandru using thematic analysis by both noting themes and subthemes as emerging from the data and as emerging from usability theory. A sample of transcripts was read by Brian McKinstry to check the coding process.

4. Results

4.1 User response rate

We interviewed 8 clinical users of the IEM system (40% of users): 4 nurses and 4 GPs (working in hypertension). We obtained data from 9 users of the Intel system (6 face-to-face, 3 via the on-line questionnaire, representing 81% of users): 2 GPs working in CHF and 7 monitors- 5 working in COPD and 2 working in CHF. None of them used both systems.

4.2 Findings

We found that healthcare workers considered the following to be the most important features of a telemonitoring website:

1. The homepage

- **Healthcare workers need a homepage which clearly distinguishes each patient's status**. In particular, they always would first of all like to **be informed about patients who have developed problems by having reading violations clearly highlighted**. For some readings such as weight (very important for CHF) one participant even suggested having a clear explanation of the way in which the reading is violating the threshold:

"*What you really want to know on the homepage, particularly with weight (...)- these are below the threshold or above the threshold. If it's below the threshold and I'm on holiday and I'm doing this remotely on Saturday-Sunday I can just ignore it, because I can change the threshold (…) I am not going to do it then. On the other hand, what I really want are the ones that are high. So, you need it either by doing it in different colours or by having "l" and "h", above or below the threshold."* (GP in CHF)

- Secondly, healthcare workers would like to **be informed about patients who have failed to take their readings, for how long this has happened and out of what reasons**:

"Any notes about that transmission, notes that they are away or in hospital or something would be quite valuable on that front page... because, particularly if you got a lot of patients on this screen you won't remember who's in hospital and who's not; it's fine if you got four or five, but if you got a lot than you do need that sort of information so that you could discount that very quickly" (GP in CHF)

- In some monitoring arrangements more than one person may be monitoring the patient. Healthcare workers felt the system should **clearly identify when a patient had been looked at to avoid work duplication**:

"There is no point looking at them [patients] *twice (…) if it was in a bigger team, you need to highlight somehow that somebody has already been looked at"* (monitor in COPD)

- **Healthcare workers need a clear indication of how a patient had been dealt with in the past accessible from the homepage.**

"There's no record of once that patient is in the red threshold, if anybody has contacted the patient, and sometimes that's about what's missing" (monitor in CHF)

"if you press acknowledge and that wee [little] *box popped up, and you just ticked "Phoned patient", "Patient requires home visit" or "Patient requires prescriptions", so wee* [little] *choices you could click that, and then, at the end of these ones you can see them* (patients) *with that ticked on, you know, and if the patient required action, that would, I think that might be useful."* (monitor in CHF)

- **Easy access to the patient's demographic details by having some of them right on the homepage or a click away**:

"Patient details should either be a click away or it should be there (…) you don't want to clutter up that first screen too much, but there should be a button on which you just click for patient details that just gives you the telephone number and the address, and all the rest you could get to if you wanted" (GP in CHF)

2. The summary page

Healthcare workers need a summary page containing the most important patient data as easily accessible from the homepage. Participants repeatedly suggested that 7-day history data containing comments from previous monitors, or information like planned holiday breaks or hospital admissions, would be useful to be included in it. If integration was possible, the summary page could get updated from the patient medical record on-the-fly, for example with changes in medication, to ensure consistency between systems:

"What would be really useful would be if, just by clicking on a patient, I could get back information on a single page for that patient, some sort of summary data. Currently, we use a separate Excel spreadsheet, which shows the last days' patient results: patient, telephone, GP, last updated, called and notes. We also give the patient an information sheet asking him to announce when he goes on vacation, but patients don't always consider that. It would thus be useful to have something on the patient telling us that the patient is out. This could appear on the summary page, which could thus include: demographics, 7-day summary, and holidays." (monitor in COPD)

3. Presenting data on patient readings

- **Healthcare workers need an option of different types of symptom data presentation (e.g. line graph or table) to fit all preferences and an option of saving such preferences for later accesses to the website.**

- **The symptom data presentation options should clearly highlight abnormal readings:**

"It's not highlighted whether it's an abnormal reading or a target reading, you just have to read your way through it. (nurse in hypertension)

- **Charts should present variation appropriately, use very different colours for the different types of readings and be appropriate for printing:**

"it can sometimes be quite difficult visually if you've got somebody who's got the heart rate and an oxygen level that run close cause it's black and blue" (monitor in COPD)

"In some ways it would be better to have, you know, [instead of one scale] *a scale on the right hand side, maybe for the pulse rate, which is different from the one on the left hand side, for the oximetry, you know? And in that way you could see the variation more readily. Or have two sets of graphs"* (GP in CHF)

4. General issues

- **Integration between the system and the electronic medical record (EMR):**

"At some point in the future it would be nice if it would be linked with other records in the practice, so that you knew what drugs they're on, what drugs have changed (...) so that when you open up this record it opens the GPass record [the EMR] *at the same time, you know, so you could move effortlessly between the two, that would be quite useful."*(GP in CHF)

The evaluated systems did not allow for integration with the EMR, which made the users' work much harder as they needed to work on two systems:

"I was using two different systems to come to an assessment, so that again is time consuming, there was no way to know if they had blood done recently and what medication they were taking, none of that was listed on this particular website." (nurse in hypertension)

- **Speed in navigation** – was seen as of utmost importance, as telemedicine is meant to allow for the care of a larger number of patients in the same work timeframe and, moreover, as many of the practices and hospitals we visited had low Internet speeds. Even generally, Suduc et al. have found that wasted time is often seen by users as the most important negative consequence of reduced web interface usability [12]. Participants suggested that navigation could be improved by having:

  - **A small number of clicks for selecting a patient**
  - **Quick patient search options** by having:
    - **A search facility for quickly finding a patient right from the homepage**. This was not available in one website:

      "that [the search facility] *is actually quite slow because, on ours, you click on 'Change patient', brings a search box, you put in the patient's name, you do 'Submit' and the box underneath it then brings the patient up again and you press submit again."* (monitor in COPD)

    - **Several options for ordering the patient list from the homepage** (alphabetically, by caretaker, by last notes) to respond to different needs:

      "you could then rearrange them in terms of alphabet or something like that, that would be quite a useful way to do, so that you could find a patient easy (…) if you had a hundred to look at it would be a lot harder [without it]*, no doubt about that."* (GP in CHF)

      "You should be able to sort them [patients] *by carer (...) because if you had 400 patients, you're not likely to have the same person monitoring all 400."* (GP in CHF)

    - **A compromise between using pagination for splitting up the patient list from the homepage and the time it takes to load all the patients from the list with a scroll**
  - **Related information** (e.g. violating symptom readings and the thresholds they violate) **placed on the same screen**, even if repeated elsewhere.
  - An **easily accessible representation of patient symptom evolution** by having:
    - **Shortcuts to popular time intervals:**

      "If there was a wee [small] *button that would say "Today's readings" see what I mean? So that when I've gone through them all* (the readings) *and I want to go back* (default is today)*..."* (monitor in CHF)

    - **Good defaults for users who do not set up personal preferences**:

      "Actually even for things such as measurement devices, you just double click on that and it just gives you the last week" (GP in CHF)

    - **Saveable options of the type of display which users prefer**:

      "I think that what you should do is say in advance that you want the data displayed graphically so when you open up the measurements it opens up graphically" (GP in CHF)
  - While the number of clicks needs to be kept to a minimum and the patient summary page is desirable **a compromise must be found between this and keeping the screen uncluttered so that users can easily find information in it**. Page cluttering was considered a major concern.

5. Proposed Prototype and Its Evaluation by Participants

To test the accuracy of our findings as regards usability, we designed a prototype of telemonitoring solution incorporating suggested improvements which we evaluated with the same group of participants. The prototype was an interactive on-line mock-up of system functions and data which only worked on example scenarios highlighting especially the functionality that users said they would like as additional/different to what they already had available. We assumed that data integration with the general practice record was possible. We evaluated the prototype together with 9 of the users from the initial evaluation, who kindly agreed to participate in this second part of the study. The participants were contacted by email and provided with the link for the prototype, a list of tasks on working scenarios of the prototype which they were asked to try out, and a link to a semi-structured questionnaire asking for their opinions,

critiques and suggestions about these tasks. The participants did not receive any training before trying out the prototype.

The questionnaire replies were analysed by Cristina Alexandru using thematic analysis, based on themes arising in the first part of the study and including new ones as they arose.

In the implementation of the prototype we used HTML for the static content, PHP running on an Apache server for the dynamic content and for communication with a MySQL database, and JavaScript for web form validation. The prototype consisted of:

1) The homepage (Figure 2), from which users could see patients as classified into four categories: normal, abnormal, 'dealt with' and not transmitted (since when and for what reasons, if known). Each category also displayed the patient's telephone number and care taker, as well as a drop-down list of actions which could be chosen as needing to be taken for a patient who was dealt with and then confirmed once performed. Patients could be ordered in each category alphabetically, by care taker and by the age of the notes healthcare workers had made on their state. A quick search facility consisting of a simple box and search selection criteria allowed users to search for a specific patient and get the results within the homepage. A patient could be selected by a single click on his name, with a clear confirmation of it becoming highlighted in colour. Two clicks on the patient's name or, alternatively, a click on a menu button, inactive if the patient was not yet selected, took users to the summary page. The homepage also displayed the patient's last 7-day 'reading history' when users clicked on any reading and allowed users to read patient notes attached to an individual patient reading or to the patient in general. Participants were generally enthusiastic about the improved homepage, but they also wanted easy access to explanations as to how high or low an aberrant reading is. They also preferred to have the option to change the time interval for the patient's 'reading history'. We offered options of scroll and pagination for patient lists, but participants usually commented that they prefer scrolls only.

Figure 2. The prototype's homepage

2) The summary page (Figure 3), which contained the patient's full personal details, contact information for the GP practice, the last 7-day history of his readings, notes made by healthcare workers on them, medication the patient was currently on, medical history data and a form where healthcare workers could enter the reasons why a patient may not be taking his readings (e.g. hospital admission), these reasons being then displayed on the homepage. The prospect of such data integration (not currently available yet) was warmly welcomed by participants. They suggested displaying the reasons for patients not sending readings, once filled in the form, in the summary page as well.

Figure 3. The summary page of the prototype

3) The measurements page, which displayed by default the patient's last 7-day readings and offered options for the healthcare worker to get different types of readings and for different timeframes as displayed either textually, graphically (with a choice of line chart or bar chart) or both (Figure 4). To improve navigation, the page offered defaults for options which were not completed and contained quick option buttons (e.g. "yesterday's readings", "last 10-day readings", etc.). It also included the facility to remember display options for later uses of the website in the same day and allowed users to save their preferences as default for all future uses. The page offered the option to view the evolution of readings as represented within individual graphs or combined ones, used two scales for representing two readings on combined graphs, used very different colours and allowed users to print the results.

4) The thresholds page, accessible from any page apart from the homepage, which allowed healthcare workers to change thresholds for different types of readings for a patient. The page incorporated medical knowledge by containing default 'obvious' limits (e.g. 100% in oxygen saturation) and allowing healthcare workers to set up limits for acceptable variation for conditions such as weight apart from higher and lower limits.

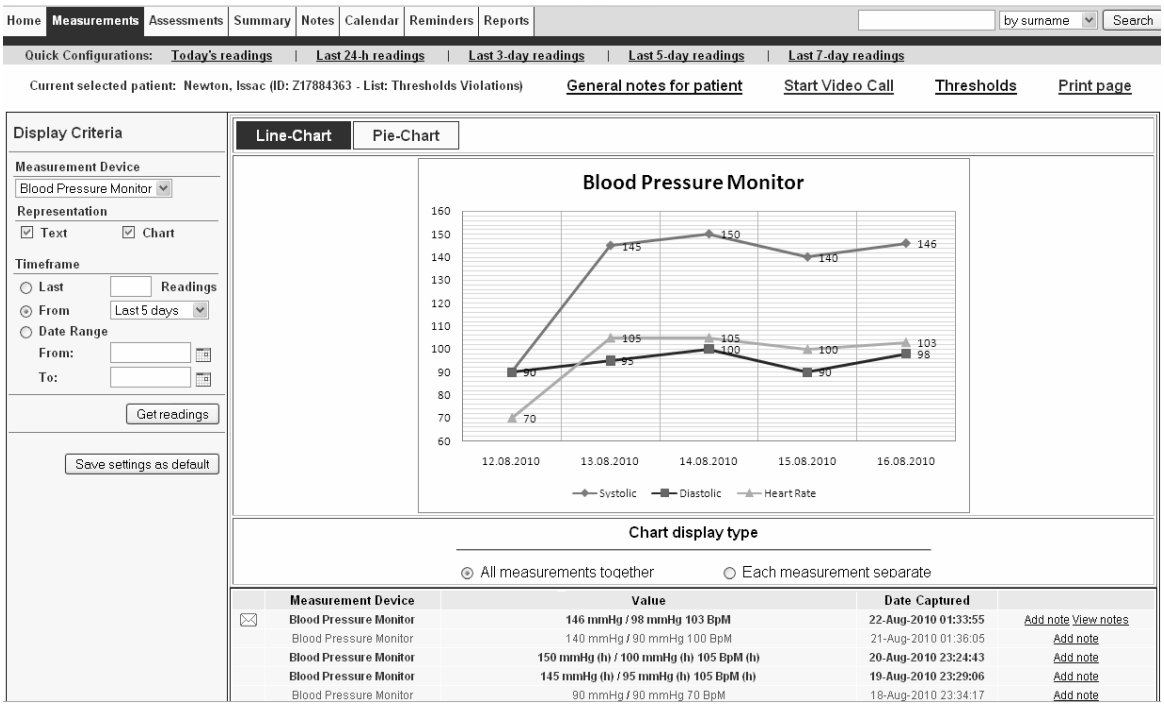

Figure 4. The prototype's measurements page, textual and graphical representation

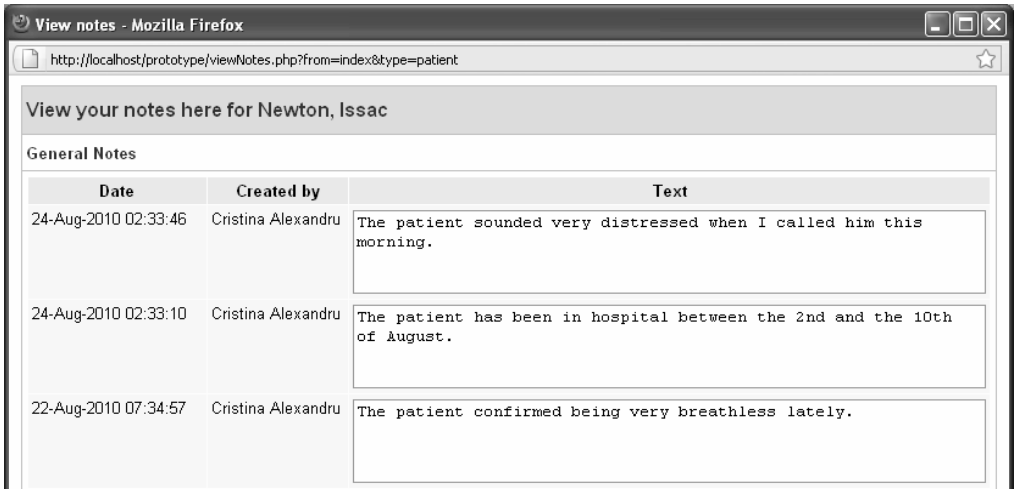

Figure 5. The prototype's "View notes" page for general notes attached to patient

5) The "Add note" page, which allowed healthcare workers to add notes regarding any communication with a patient either as attached to a single reading or generally to the patient and "View note" pages (Figure 5) where they could then see a history of the notes. A general ***notes page*** accessible anytime from a menu button displayed the notes on all the patients, which could be filtered by time intervals.

5. Discussion and Conclusion

Our results on usability are supported by similar findings in the related area of EMRs made by Rose et al. ([13]), who highlighted the importance of quick navigation, quick access through shortcuts, large information needs versus cluttered screens, focused information and good highlighting by a good use of colouring. Also in the field of EMRs and echoing our results, Wyatt and Wright ([14]) and Nygren et al. ([15]) have suggested guidelines for increasing the speed and efficiency of searching clinical records, suggesting many of the features we found were desirable in telemonitoring 'back-ends'.

In addition to the findings of the authors above, we learned that healthcare workers desire more customisability for quicker navigation, the support of different types of data presentation to suit all user preferences and the integration of telemedicine systems (usually standalone), with the patients' general medical records to better inform treatment decisions, avoid switching between systems and double entry.

Important limitations of our study are the fact that we investigated only two telemonitoring websites, post-release and with a relatively small number of participants. However, the websites represented two very different types of approach and a range of conditions and, as a high number of the potential participants were interviewed, we believe their views to be representative. Normally, usability studies are carried out with novice users, but the fact that usability problems persisted despite experience suggest that training alone is unlikely to overcome them. Our results support the need for integrating usability studies with ongoing technical development of telemonitoring websites. This will improve the efficiency and safety of managing telemedicine and is likely to lead to a higher system acceptance rate.

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