

USABILITY OF A DIABETES TELEMAGEMENT SYSTEM

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INTRODUCTION

Telecommunication technologies have been shown to be effective at enabling the management of diabetes and other chronic diseases^{1,2}. However, their widespread success has been hindered by issues of usability. Difficult-to-navigate software applications can lead to more time spent retrieving clinical data instead of providing patient care. Further, they force the clinician to commit data to memory when critical data does not appear on the same page³. Mobile telephones used by older patients for disease management can be problematic when buttons are not well-spaced, leading to lack of tactile differentiation. Low screen contrast, multi-step functions, little feedback, and excessive scrolling can also be problematic⁴. The severity of these design issues is compounded in diabetic patients with associated vision impairment and reduced dexterity. For these reasons, there has been low adoption of these systems. A more user-centric design approach would thus be beneficial.

This study evaluated the usability of a prototype system which employs a mobile phone based remote monitoring system of diabetic hypertensive patients. The objective was to make design recommendations regarding the system's two user interfaces as part of the iterative development cycle in order to improve ease and adherence of use, and user satisfaction.

BACKGROUND

The diabetes telemanagement (DT) system being developed at the University Health Network consists of a mobile telephone (BlackBerry 7130e), a Bluetooth-enabled digital upper arm blood pressure monitor (A&D Medical UA767BT), a blood glucose monitor (LifeScan One Touch Ultra) connected to a custom-built Bluetooth adaptor, and a web-based viewer application. The monitors measure the patient's blood pressure (BP) and blood glucose (BG) and automatically transfer the data wirelessly to the mobile phone. For BG readings, the mobile phone prompts the user to enter details about their reading by

selecting from menu choices. The mobile phone communicates the data to a central server which responds with an automated pre-programmed message for the patient about their reading. For notifications to the patient that require further attention, an automated telephone call is also made to the patient's home phone. Patients can also use the mobile phone to view their BP and BG data in the following formats: (i) log, (ii) summary report, and (iii) graph. The clinician-end of the system is a secured website through which clinicians are able to: (i) access their patient's BP and BG monitoring results, (ii) receive alerts about out-of-range readings and in adherence to a reading schedule, and (iii) modify the target reading range as well as thresholds for triggering alerts.

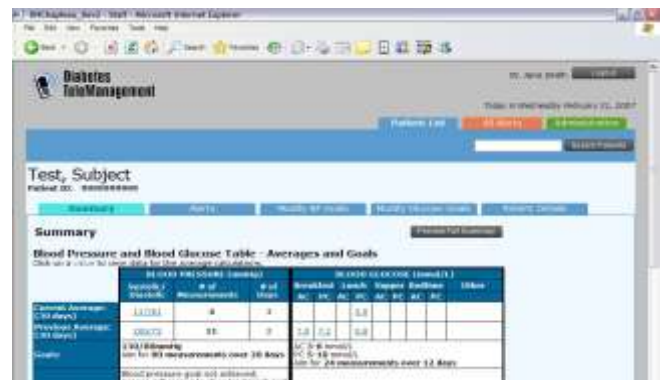


Figure 1: Screenshots of the mobile phone & web-based viewer interfaces

METHODS

To assess the usability of the system, laboratory-based usability testing of both the website and mobile phone interfaces was conducted. Six clinicians (4 family physicians and 2 diabetes clinic nurses) and four hypertensive type II diabetes patients participated in the website and mobile phone interface evaluations, respectively. A pre-study survey was completed by participants to collect demographic data and technological expertise information. Participants were then given a realistic scenario wherein they performed specific tasks with the system while thinking-aloud and commenting on their experiences and impressions. To capture the participants' first impressions and natural behaviours, neither group was given any formal training on the system. For website testing, clinicians used the website to find three sets of simulated patient BP and BG data. The facilitator remained behind a one-way mirror and observed the clinicians' interactions with the website via remote-viewing software (TechSmith Morae v1.3). For mobile phone testing, patients were asked to use the system (BP monitor, BG monitor, and mobile phone) given a series of tasks in two scenarios while the facilitator observed nearby. Table 1 lists the tasks performed by each of the clinicians and patients. Participants completed a post-test survey to assess perceived ease of use and satisfaction of the system on a 1-to-5 Likert scale. The one-hour testing sessions were conducted in the usability laboratories at the Centre for Global eHealth Innovation in accordance with the Toronto Academic Health Sciences Network Research Ethics Board's approval.

Table 1: Participant Tasks

Clinician Tasks	Patient Tasks
1. Log in	1. Take simulated BP
2. Search for patient	2. Take simulated BG
3. Navigate to the summary table & interpret	3. Enter BG details
4. Navigate to graphs & interpret	4. Navigate to last reading
5. Navigate to alerts & interpret	5. Navigate to log & interpret
6. Modify goals	6. Navigate to report & interpret
	7. Navigate to graphs & interpret
	8. Navigate to details & interpret

All observational data was qualitatively analyzed and deficiencies in the DT system were categorized according to usability principles or heuristics that were violated. Heuristics were chosen from established sources and included such categories as Content, Accessibility, Visibility, Autonomy, Usefulness, Navigation, Convention, Readability, and Feedback^{5,6,7}. The issues were then prioritized

according to severity. High priority issues included those that could have safety implications if left unaddressed. Low priority issues included those that could result in user frustration and inefficiencies if left unaddressed.

RESULTS & DISCUSSION

The pre-study survey showed that clinicians (ages 35 to 64) were experienced with computers, finding both computers and the internet: '*neither easy nor difficult to use*' (33.3%) or '*very easy to use*' (66.6%). The patients (ages 55 to 84) had a wide range of experience with respect to mobile phones. Three out of the four did not own a mobile phone, while the fourth patient owned and used both a mobile phone and a personal digital assistant daily. In terms of their ability to interact with the mobile phone, all patients were visually impaired, two of whom performed testing without their corrective lenses, and one patient reported having arthritis.

Usability testing identified a total of 46 issues with the DT system (22 website issues and 24 mobile phone issues). Table 2 shows the high priority issues for each interface and a select number of low priority issues. The high priority usability issues were related to: (i) inclusion of incorrect data in the patient's record, and (ii) incorrect data interpretation. Potential for incorrect data to be entered via the mobile phone existed because the phone did not present the user with an undo option after entering details regarding BG readings. So, despite the fact that BG readings can be automatically transferred to the mobile phone, false data can still make its way into the patient's record. This false data could negatively affect clinical decision-making, leading to potential patient safety issues.

Incorrect interpretation of data could result in both the clinician and patient responding in an inappropriate manner. During website testing, clinicians were not able to interpret adherence to the monitoring schedule from the BG graphs. This misinterpretation occurred because graphs showing trends were misleading: BP trends displayed a linear time while BG trends did not display a linear time. Consequently, it is possible for clinicians to not investigate missing readings, unless they examine the patient's alert list. Thus, there is potential for physicians to make a misinformed treatment decision.

During mobile phone testing, readings and alerts in the log were not readily distinguishable from one another. As such, patients overlooked the alerts when viewing the log and interpreted their readings as being within target range. They would then be misinformed about their monitoring trend unless they had navigated to the

Table 2: Select Usability Issues & Recommendations

	Issue	Impact	Severity (Heuristic Violated)	Recommendation
WEB VIEWER	1) Information regarding a patient's severe readings or alerts is not apparent on the patient's main page.	Clinician concludes that there are no alerts for the patient which jeopardizes the patient's safety. Clinician navigates to the patient's alerts page to check if the patient has any alerts. This slows down the user.	High (Content)	Include the number and type of severe readings or alerts on the patient's main page. Allow the data to link to further details which would include the exact reading value as well as whether or not the clinician has already seen it.
	2) Formatting of all graphs showing trends should be consistent.	Clinician assumes that the axes increase linearly on all graphs showing trends. This leads to incorrect trend interpretation which jeopardizes patient safety.	High (Content)	Ensure that all graphs have consistent formatting. Specifically, ensure that all graphs showing trends increase linearly.
	3) The commonly used 'Back' browser button causes the web viewer to fail.	Clinician exits website unexpectedly. This frustrates, confuses, and slows down the user.	Low (Convention)	Ensure that the 'Back' browser button functions as expected.
	4) The commonly used mouseover interaction does not work.	Clinician navigates away from the patient's graph and towards the reading log in order to find exact data values. This slows down the user.	Low (Accessibility)	Enable the graph's data point values to appear whenever the user's pointer is placed over them.
	5) Expectation for two-way communication via the website is not met.	Clinician cannot communicate directly with the patient via the website.	Low (Autonomy)	Implement a text messaging feature which gives the option to write a customized message or send a pre-made message to the patient.
MOBILE TELEPHONE	1) Data entry cannot be reversed.	Patient inadvertently enters faulty data. This can lead to an incorrect treatment plan.	High (Content)	Prompt the patient to confirm if the data entered is correct. A confirmation request could read, "Is this correct: Before Breakfast? 1- Yes, 2 – No". If the patient enters 2, then the application should return the user to the Details Needed screen.
	2) The automated instructional message sent to the patient in response to readings is not sufficiently detailed.	Patient does not know how to respond to readings when e.g. the message reads, "Please take your medication and follow a healthy lifestyle".	High (Content)	When setting up each patient to use the system, ensure that the messages are catered to them according to their treatment plan.
	3) Severe readings or alerts are not apparent.	Patient overlooks severe readings.	High (Accessibility)	Emphasize severe readings by: i) changing the background colour of the alert popup to red, and ii) bolding the alert line in the patient's log.
	4) Graphical display is not sufficiently detailed.	Patient cannot interpret the graphs correctly. This leads to frustration and slows down the user.	Low (Readability)	Ensure graphs have enough detail (e.g. axes labels, axes markings, normal data range) to interpret the graph.
	5) Instructions on how to navigate between screens is missing.	Patient guesses at how to exit screen. This frustrates, confuses, and slows down the user.	Low (Navigation)	Include instruction (e.g. Press 1 for Menu; Press 2 to go back) on each screen.
	6) Phone settings interfere with the patient's ability to use the application.	Patient assumes something has gone wrong when e.g. i) the screen light becomes dim and ii) the phone goes into sleep mode. The patient then guesses at how to navigate.	Low (Accessibility)	Discuss the phone's settings and how to handle and change them in the system manual. For waking up the screen, allow the patient to press any key to wake up the screen without navigating the user to another screen.

summary report or graphs. Messages received in response to the readings could also confuse the patient about what action they should take in response to an alert. One patient pointed out that the message, "Please take your medication..." was confusing as he

had already taken his regular medication dose and any further usage would not comply with his treatment plan. The preprogrammed response messages should reflect the actions that the clinician and patient have agreed to follow when certain readings occur.

The post-study survey revealed that clinicians found the website: *'neither easy nor difficult to use'* (50%), *'somewhat easy to use'* (33.3%), or *'very easy to use'* (16.7%). This ease of use rating is slightly lower than the clinicians' rating of computers and the internet, indicating there is room for improvement with the website. Although clinicians identified the graphs as the most useful feature of the web viewer they all failed to realize that they were incorrectly interpreting the data. This emphasizes the severity of the problems with the display of data via the graphs. Finally, patients rated the mobile phone: *'somewhat easy'* (75%) to *'very easy to use'* (25%). Thus, they were mostly satisfied even though their task performance was not great. They were also mostly satisfied with the phone hardware features, stating that they were *'neither satisfied nor dissatisfied'* (25%) or *'somewhat satisfied'* (75%) with the scroll wheel and *'somewhat satisfied'* (100%) with the keypad buttons. This satisfaction level with the scroll wheel was unexpected since the scroll wheel, being a feature unique to the BlackBerry mobile phone, would be something new to users never having used a BlackBerry phone before. Further, the action of scrolling was anticipated to be especially difficult since all of the patients held the phone with both hands instead of with their right hand, the position which works best when handling the scroll wheel located on the right side of the phone. The high level of satisfaction with the keypad buttons was also unexpected since 2 of the 4 patients were not wearing their corrective lenses during the usability testing and small keypad buttons are a common usability issue.

During patient-end testing, some issues with the home monitors were identified. Patients had difficulty measuring simulated BG samples since they were not able to remove the BG monitor from its case as they would normally do with their home monitor. This issue suggests that the bulky Bluetooth adaptor should be modified to allow for removal of the monitor from its case. Alternatively, the BG monitor could be replaced with one of comparable test response time and sample size but that has a Bluetooth chip within the monitor instead of a Bluetooth adaptor attached to it. Either change would allow patients to use the BG monitor as they would normally. With respect to the BP monitor, patients experienced difficulty in placing the cuff on their upper arm. The confusion was rooted in an ambiguous arrow indicator on the cuff. Patients were unsure of whether the arrow was meant to be aligned with the cuff tubing or with the brachial artery. This suggests that new cuffs should be considered with indicators that better guide the patient to proper use.

Limitations

According to Nielson, usability testing should be conducted at 3 design development stages each with 5 participants in order to achieve saturation in the number of usability issues uncovered⁸. In this study, the clinician testing met this sample size requirement, but patient testing did not. With the addition of one or two more patients, further issues may have been identified, and the severity of the issues may have been better revealed. Also, further usability testing would evaluate the effectiveness of implemented design changes.

CONCLUSIONS

Relative to other electronic health applications, the DT system appears simple. However, many high and low priority usability issues were identified in this evaluation through the observation of users. The clinician and patient perceptions of the system were not entirely positive in terms of ease of use and satisfaction, indicating that there is room for improvement. The methods and design recommendations detailed herein can be applied to the design of remote monitoring systems for additional vital sign monitoring, such as weight and blood oxygen saturation as well as other chronic diseases and rehabilitation treatments.

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