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Touchscreen Task Efficiency and Learnability in an Electronic Medical Record at the Point-of-Care

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Abstract

The objective of this study was to determine the relative efficiency of novices compared to a prediction of skilled use when performing tasks using the touchscreen interface of an EMR developed in Malawi. We observed novice users performing touchscreen tasks and recorded timestamp data from their performances. Using a predictive human performance modeling tool, the authors predicted the skilled task performance time for each task. Efficiency and rates of error were evaluated with respect to user interface design. Nineteen participants performed 31 EMR tasks seven times for a total of 4,123 observed performances. We analyzed twelve representative tasks leaving 1,596 performances featuring six user interface designs. Mean novice performance time was significantly slower than mean predicted skilled performance time (p < 0.001). However, novices performed faster than the predicted skilled level in 208 (13%) of successful task performances. These findings suggest the user interface design supports a primary design goal of the EMR – to allow novice users to perform tasks efficiently and effectively.

Keywords:

Electronic medical records, Developing countries, Human computer interaction, Usability, Predictive human performance modeling

Introduction

Electronic Medical Records (EMRs) provide important benefits to healthcare delivery such as improving the quality of patient care, decreasing medical errors, and reducing costs [1-3]. In developing countries and low-resource settings we believe the potential of EMRs to improve patient care is magnified, given the utility of existing paper medical record systems. However, a combination of technical and socioeconomic challenges impedes the successful adoption of EMRs in these settings. The healthcare environment is characterized by a lack of a reliable infrastructure, large-scale health crises such as HIV/AIDS, and a health worker shortage [4]. An EMR implemented in this context must support the tasks of clinicians with no prior computing experience who endure poor working conditions and a high patient-to-clinician ratio. High rates of staff turnover further complicate the successful implementation of EMRs by increasing the number of new clinicians who need to learn to use a system efficiently and effectively.

Learnability and efficiency are two aspects of system usability that are critical factors for successful implementation of health information technology in developing countries. Learnability refers to the effectiveness with which a new user can perform tasks. Efficiency is the time required for a user to perform a task, given a design. Our long-term goal is to develop an EMR user interface that is both learnable and efficient for novices and experienced users alike in a developing country. The objective of this study was to evaluate the efficiency and learnability of an EMR designed to manage HIV/AIDS patient records in Malawi. In particular we wanted to measure the efficiency of the EMR for new users in comparison with the efficiency level that experienced users should be able to attain given a particular user interface design. As a first step towards evaluating the design, we used health sciences students at the University of Pittsburgh to represent novice EMR users with the intent to refine our evaluation with novice users in Malawi.

Baobab Anti-Retroviral Therapy (BART) EMR in Malawi

Malawi, like many countries in sub-Saharan Africa, is experiencing a devastating HIV/AIDS epidemic that has infected close to 1 million people, or about 8% of the population. Baobab Health Trust, a Malawian non-governmental organization, has partnered with Malawi's Ministry of Health to implement an EMR in six HIV/AIDS clinics to improve the delivery of care and support monitoring and evaluation of Anti-Retroviral Therapy (ART). Clinics using the Baobab ART (BART) EMR were providing free ART to 23,667 patients as of December, 2009. A core feature of the BART EMR is a Touchscreen Clinical Workstation (TCW) deployed at the point-of-care (Figure 1). The TCW is a low-cost information appliance that captures data during patient visits. TCWs support clinical decision-making by guiding health workers through patient en-

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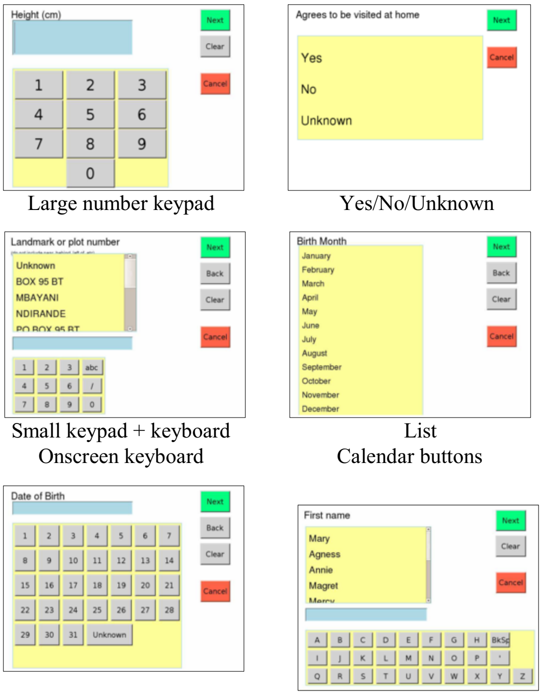
counters consistent with national treatment protocols for ART [5, 6].

Baobab Health Trust has innovated hardware and software solutions to introduce point-of-care computing in low-resource settings. These innovations include alternative power approaches, adaptation of hardware to increase system reliability in environments with high humidity or dust, and large-button touchscreen user interfaces. The TCW user interfaces are wizard-like, presenting the user with a single question per screen (Figure 2). The constraints of the task and the setting – that is, a multistep, ordered process often completed by individuals lacking domain knowledge – lends itself to a wizard-like user interface design. The choice of a wizard-like design for the touchscreen interface does not, however, guarantee efficiency.



Large number keypad | Yes/No/Unknown

Small keypad + keyboard Onscreen keyboard | List Calendar buttons

Figure 2- Six touchscreen user interface designs for collection of data at the point-of-care

HCI4D

Human Computer Interaction for Development (HCI4D) has emerged over the past decade within the field of HCI as a specialization that seeks to translate the tools and methods of HCI in developed regions for use in low-resource settings. Practitioners of HCI4D believe that the challenges and methods of HCI in developed regions will resemble the methods required in low-resource settings. A fundamental HCI principle known as "the user is not like me", which refers to the inherent differences in perspective between system developers and users, would appear to support that belief. However, the community has only recently begun to establish shared knowledge about the differences between users in low resource settings and users in the developed world [7].

Figure 1- A health worker in Malawi uses a touchscreen workstation at the point-of-care

Predictive Human Performance Modeling

Since the early 1980s, HCI researchers have addressed the problem of how to predict the efficiency with which a skilled user will be able to complete a task using a specified interface design. An HCI technique called the Keystroke Level Model (KLM) has been refined and tested to become a reliable and validated tool for predictive human performance modeling. KLM is capable of predicting the mean time for task completion by a skilled user, using a given system design, with an approximate 20% margin of error [8].

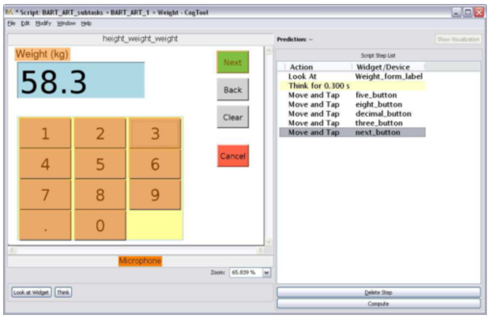


Figure 3 - CogTool interface for task demonstration using a BART user interface screenshot

CogTool is a free software application that automates the process of creating a predictive model using KLM and allows a user to rapidly create predictive models based on the user input mode, such as mouse and keyboard, voice, or touchscreen [9]. To predict a task performance time the user first draws overlays on a screenshot or mock-up of the task interface to indicate the location, size, and other properties of the widgets that must be manipulated to successfully complete a task. After preparing overlays, the user demonstrates the optimal sequence of steps required to perform a task (Figure 3).

Upon the completion of the task demonstration, CogTool generates a KLM prediction that yields a time estimate in milliseconds. The resulting estimate is the predicted total time required for a skilled user to perform a given task.

Methods

To measure relative efficiency of use, we first selected commonly performed touchscreen tasks from the EMR for evaluation. We observed novice users performing the touchscreen tasks and recorded timestamp data from their performances. Using CogTool, we predicted the skilled task performance time for each task.

Novice Human Performance Measurement

Participants

Participants were required to be adult, novice touchscreen EMR users, without prior experience using a touchscreen interface for an EMR. No prior medical training or familiarity with computers was required for the participants to be eligible for the study. Participants were health sciences students recruited at the University of Pittsburgh using posted flyers and were offered a gift card worth $25 for their participation.

Task

We selected 31 EMR tasks that are commonly performed by nurses and patient registration clerks in an ART clinic. The selected tasks did not require prior knowledge of HIV/AIDS disease management. The tasks belonged to the following clinical work processes: patient registration, patient medical history, and patient vitals collection. Patient registration tasks required patient information such as name, address, and contact details. Questions about medical history required information about the patient's prior ART treatment. Patient vitals measurement questions collected the patient's height and current weight.

User Session

We designed a five-minute training period to simulate the training provided to users of the EMR in Malawi. The session included demonstration of a representative task and a description of the core functionality of the system. Additionally we introduced concepts in the EMR that are unique to patient care in Malawi. For example we explained the concept of “ancestral traditional authority”, referring to the tribal home area of the patient, which would be unfamiliar to most participants. Once the training session was completed we gave participants an opportunity to ask any questions about the system. Following a time for questions we instructed participants to attempt to solve any subsequent problems they encountered on their own, instead of asking for help.

We prepared a series of seven mock patient encounters with an actor playing the role of a patient responding to questions from the user. The actor was prepared to play the role of all seven different patients during the user session.

Before the patient encounter began, participants practiced one representative task in the form of logging into the system with a username and password. For each patient encounter, participants performed all 31 selected tasks once. Most tasks required system users to directly ask the patient for information before entering the data into the system using the touchscreen computer. During the task performances we recorded written observations about problems that users encountered and unanticipated user behaviors.

We designed the session to last up to a maximum of one hour or seven patient encounters. Following the session, participants answered a one-page questionnaire about their computing experience and their subjective satisfaction level when using the EMR.

Event Logging

While participants used the system, the EMR software logged their activities by recording timestamp, contextual and value data entered for each user interface event. Examples of user interface events include button presses, page load time, and list item selections. For each event, the application recorded the current time, user ID, task name, and interface widget name.

Predictive Human Performance Modeling

To measure skilled efficiency of the EMR, we used CogTool to predict estimated performance times for skilled use of the 31 tasks. CogTool allowed us to rapidly build a predictive model of skilled human performance for each task.

The task models included not only the EMR user interface events, but also the time required for the user to see the question displayed by the EMR, ask the patient for information, hear the patient's response, and manipulate the interface to successfully complete the task based on the patient's answer. After we created the model for each task using CogTool, the software generated an estimated time prediction in milliseconds for each task.

Efficiency and Errors

We recorded novice performance errors to be able to analyze rates of errors in novice task performance with respect to efficiency and interface type, and to determine where novices succeeded or failed to complete tasks. Performance errors refer to any user interface event performed by the participant that was not modeled as part of the optimal sequence to successfully complete a task. For example, if a participant made a typographical error, then used the backspace button to correct the mistake, this was considered a performance error in a successfully completed task. Successful completion of a task is defined as having entered the correct value specified in the mock-patient data set for each patient encounter.

Results

The purpose of this study was to determine how efficiently novices perform touchscreen EMR tasks relative to a prediction of skilled use. To accomplish our goals, we compared

Table 1- Novice errors for six interface types

Interface type	Performed Tasks	Tasks with corrected errors		Successful tasks		Failed tasks		Tasks with missing data	
List	266	8	(3%)	250	(94%)	0	(0%)	16	(6%)
Calendar buttons	266	16	(6%)	264	(99%)	1	(0%)	1	(0%)
Yes/No/Unknown	399	13	(3%)	390	(98%)	2	(1%)	7	(2%)
Large number keypad	266	15	(6%)	259	(97%)	3	(1%)	4	(2%)
Onscreen keyboard	266	47	(19%)	252	(95%)	14	(5%)	0	(0%)
Small keypad + keyboard	133	78	(70%)	111	(83%)	22	(17%)	0	(0%)
Total:	1,596	177	(11%)	1,526	(96%)	42	(3%)	28	(2%)

novice performance times to the predicted times for skilled task performance. Additionally we analyzed the novices' rates of error and efficiency with respect to the user interface design.

We conducted a preliminary analysis of twelve out of the 31 total tasks. The user interfaces for the twelve selected tasks feature six designs (Figure 2) that are representative of the interface designs for all 31 tasks. The resulting data set contains 1,596 observed task performances (Table 1).

We created preliminary CogTool models for the use of a touchscreen EMR based on observed data collected in a pilot study.[10] Using the results of the pilot study, we calibrated the CogTool model to improve prediction accuracy for skilled task performance. We used CogTool to predict a skilled performance time in milliseconds for each of the twelve tasks.

Participants

Nineteen health sciences students from the University of Pittsburgh responded to posted flyers and participated in the study as novices. All participants performed the 31 tasks seven times for a total of 4,123 observed task performances. All of the participants performed the seven patient encounters in less than one hour.

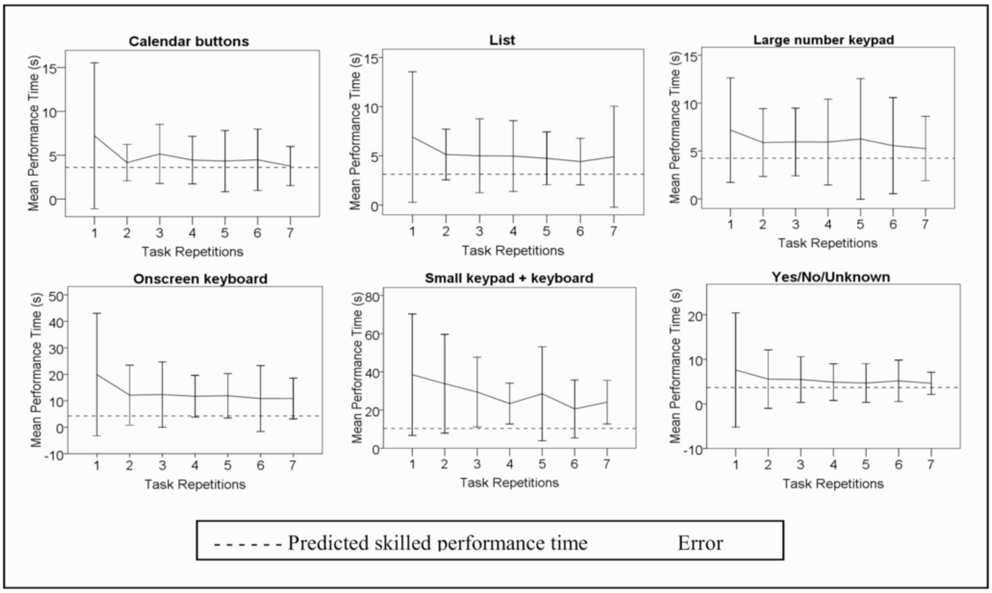


Figure 4-Mean novice task performance time by user interface design

Efficiency and Learnability

Figure 4 displays the mean novice task performance time and the predicted skilled performance time for the six interface designs. Mean novice performance for all tasks was significantly slower than the predictions of skilled use (Wilcoxon $Z = -18.58$, $p < 0.001$). Although mean novice performance times were slower, novices performed tasks faster than the predicted skilled level in 208 (13%) of the observed task performances. Novices performed within 20% of the predicted skilled level (the accepted standard margin of error for KLM predictions) in 444 (28%) of all observed task performances. Performance times for interfaces that did not require onscreen typing (Calendar buttons, List, Large number keypad, Yes/No/Unknown) were faster than performance times for interfaces that required onscreen typing (Onscreen keyboard, Small keypad + keyboard).

Errors

Table 1 displays the number of novice task performances containing one or more corrected errors and tasks successfully completed for the six interface types. Novice users completed 96% of task performances successfully. Tasks requiring the use of the onscreen typing contained the highest rate of tasks with performance errors (70%) and lowest rate of successful task completion (83%).

Conclusion

Our findings suggest that, while novice EMR users perform touchscreen tasks more slowly than predictions of skilled use, they are able to perform at a skilled level some of the time within the first hour of system use. Novices were able to perform tasks within the margin of error for the predicted skilled performance times in 28% of the task performances. This is important because a primary design goal of the EMR is to allow novice users to perform tasks efficiently and effectively.

Performance times were highly variable between novice participants for all tasks, but it is common for task performance times in user studies to vary by as much as an order of magnitude.[11] However, not all interfaces demonstrated equivalent variability in task performance. In particular the variability in performance times for interfaces containing an onscreen keyboard was noticeably higher than for other interface types. Similarly, the onscreen keyboard interfaces had the lowest rates of successful task completion and the highest rates of performance errors compared to other interface types. A possible explanation for the poorer performances with onscreen typing tasks is firstly that the keyboard used an alphabetical layout while most participants were accustomed to a qwerty keyboard layout, and secondly that onscreen typing tasks required two to seven times more touches than other tasks – increasing the overall complexity for onscreen typing tasks.

A primary limitation of this study is the differences between users recruited in Pittsburgh and the typical users of the system in Malawi. Future work will measure novice performance for users with the cultural, educational and socioeconomic background that is representative of EMR users in Malawi.

Acknowledgments

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