Using a Low-Cost Simulation Approach for Assessing the Impact of a Medication Administration System on Workflow

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Abstract. This paper describes the analysis of the impact of a medication administration system on clinical workflow. The methodological framework employed was based on in-depth analysis of simulated user interactions with a medication administration system. The approach involved the collection of rich data consisting of audio and video recordings of interactions between 16 subjects (5 nurses and 11 physicians) as they interacted with a medication administration system. Methodological considerations and issues in conducting such studies are discussed. The study indicated that use of the system would have a significant impact on nurse and physician workflow and that this impact could be accurately identified using simulation approaches prior to widespread release of such systems in real clinical environments.

Keywords. Human interfaces, user interfaces, EPR-CPR-EMR

Introduction

Simulation methods have been used in biomedical informatics to study aspects of human computer interaction in a number of health research domains including human factors, usability engineering, doctor-patient interactions involving technology, health professional decision-making, and new device testing [1-5]. In this paper we describe application of a new approach towards evaluating the effects of health information systems upon clinical workflow. The system under study was a medication administration system that was integrated with bar-coding technology. The system allows the doctor or nurse to scan an RFID bracelet to identify the patient and to scan labels on medication bags to verify and document medication administration.

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1. Background and Motivation

Health information systems can have a significant impact upon clinician work. The impact of health information systems upon clinician work has been both positive (e.g. reducing medical error, length of stay) and negative (e.g. altering traditional workflow patterns that promote clinician communication and coordination of work). This has led a number of researchers to theorize about the socio-technical implications (i.e. task-technology fit) between health information systems and real world clinical environments [6]. More specifically, some researchers have suggested many of the difficulties experienced when implementing health information systems arise from a poor fit between clinical tasks and technology, leading to unintended clinical practice and workflow effects [6-7]. Over the past decade considerable researcher effort and energy has been directed towards documenting the unintended effects of technology upon clinician workflow using observational approaches in real life settings well after a health information system has been deployed. More recently, researchers have been advocating the use of simulations as a methodology for assessing the potential impact of health information systems upon clinician work [5]. Simulations allow clinicians and informaticians to determine the impact of a system and improve workflow changes before the system is deployed in a real world context. Specifically, we explore the value of using simulations that involve users interacting with information systems and devices in simulated clinical environments as they perform tasks in order to determine their impact before system release.

2. Methods

Subjects: Sixteen subjects participated in this study: 5 nurses and 11 doctors. All were employed at the hospital where the system under study was to be implemented.

Simulation Environment: The study was conducted in a real hospital room. Equipment included a laptop computer on a cart running the commercial medication administration system under study. The “patient” consisted of a dummy (i.e. a mannequin). In the room there was a medication cart with IV bags and medications.

Recording Equipment: To record the human-computer interaction in its entirety, the commercially available screen recording program Hypercam © was installed on the laptop on the cart running the medication order entry system. Hypercam© allows computer screens to be recorded digitally as movie. In addition, a microphone was placed on the cart to pick up subjects’ verbalizations while they interacted with the system and the patient. A Sony mini-DVD camcorder (mounted on a tripod) was used to record the physical activities of the subjects (e.g. nurses and doctors) as they alternated between working on the computer and interacting directly with the patient.

Task and Procedure: The subjects were instructed to log into the medication order entry system, scan the patient’s identification wrist band (to confirm their identity) and then carry out a range of medication orders indicated for that patient (involving administration of intravenous medications as well as interactions with the medication order entry system to obtain orders and confirm their completion). This included routine tasks such as administering a once a day oral medication to a patient to more
atypical tasks such as mixing a series of intravenous (IV) medications and then administering via an IV pump. At the end of completing the set of medication administration tasks (which were recorded in their entirety) a semi-structured interview was conducted with the subject. The prompts used in the interview included the following: (a) Did you have any difficulty with the task? (b) Did you have any difficulties with the barcode reader? (c) Did you have any difficulties during the work process?

**Data Analysis:** The audio portion of the simulation session containing verbalizations from the subject were transcribed in their entirety. The audio portion of the simulation were then uploaded to a research video annotation program known as Transana which allowed for the audio portion of the session to be linked to both video views (i.e. of the computer screens as captured using Hypercam and the physical view of the subjects captured using the camcorder). This allowed for both views of the simulation to be viewed, time stamped, coded and analyzed simultaneously (as shown in Figure 1).

![Figure 1. Integrated views of the computer screens and of the subject’s physical interactions.](image)

Applying a usability coding scheme, modified from Kushniruk and Patel [2], the researchers watched the video and annotated the corresponding transcripts and post-task interviews to identify: (a) human-computer interaction actions, such as selection of patients from a drop-down list and confirmation of orders, (b) physical activities, such as hanging an IV bag etc., (c) potential problems in the workflow, and (d) conceptual themes regarding impact of the system on workflow.

### 3. Results

Each hour of video data took approximately 2 hours for two experimenters to code and analyze. The coding was reviewed by the two experimenters with minor disagreement.
being resolved during subsequent discussion. An excerpt from the coded transcript of a nurse while carrying out the required tasks is given below (along with the post task interview). The numbers in the example correspond to the actual time elapsed on the video counter. Annotations and codes are given in caps:

**MEDICATION ORDER INFORMATION OBTAINED BY NURSE**
00:14 NURSE SEARCHES FOR PATIENT ON THE COMPUTER
00:45 NURSE VIEWS ORDER LIST ON THE SCREEN
00:51 NURSE SELECTS MEDICATION ORDER FROM LIST
00:55 VERIFICATION SCREEN APPEARS

**NURSE WALKS OVER TO PATIENT TO CHECK IDENTIFICATION**
00:59 NURSE TALKS TO PATIENT - “Nice to meet you. I will now give you an IV drip”
01:09 NURSE SCANS PATIENT IDENTIFICATION (FROM PATIENT’S WRIST BAND)
01:10 VERIFICATION SCREEN AUTOMATICALLY UPDATES

**NURSE WALKS BACK TO COMPUTER**
01:25 NURSE VIEWS EXECUTION INFORMATION ON THE COMPUTER

**NURSE WALKS OVER TO PATIENT AND SETS MEDICATION BAG**
03:15 NURSE CONFIRMS ADMINISTRATION OF MEDICATION ON THE COMPUTER

**POST-TASK INTERVIEW:**
Experimenter: Did you have any difficulty with the task?
Subject: I’m used to this operation, but sometimes it is hard to use the barcode reader when the barcode is not clearly printed.
Experimenter: Did you have any difficulties with the barcode reader?
Subject: In today’s operation there were no problems. But in the real situation, sometimes the scanner doesn’t respond to the barcode. Also, sometimes the cord of the scanner is too short to reach the patient.
Experimenter: Did you have any difficulty during the work process?
Subject: In general, I want a more simplified system for the verification process. The more patients there are, the more difficult the verification would become.

4. Observational Data and Emergent Conceptual Themes

This section will present the findings from our simulation from both the observational component of the study (i.e. from analysis of the video recordings of the subjects while carrying out tasks) as well as from thematic analysis of the post-task interview transcripts. From this analysis, we identified 6 potential issues described below.

4.1. Sequence of Workflow Activities

The analysis of recordings of the users’ interactions and activities indicated that the system imposed a fixed and relatively rigid sequential order of activities (that could not easily be deviated from) in order to document the medication administration. As illustrated in the excerpt given above, the user of the system proceeds from viewing the order list, verifying the patient, selecting an order, verifying the medication, scanning the medication bag, administering the medication, confirming the administration and
then proceeds to another medication. In addition, the interview data indicated that the majority of subjects felt the verification process could be simplified.

4.2. Response During Urgent Situation

A recurrent theme that emerged from the analysis of the post-task interview transcripts indicated concern by subjects of how the system might affect workflow during periods of urgency where the physician or nurse might need to leave the prescribed sequence imposed by the computer system to deal with emerging clinical situations. In considering the ordering of tasks that the system imposed for entry of all medications, one nurse subject stated that “sometimes in the emergency we have to skip one of these procedures due to its time-taking process and someone might need urgent help, but with this system I don’t think I’d be able to do that”.

4.3. Increased Work Activity

In conducting the simulations, as the number and complexity of medications to be entered increased, as the workflow imposed by the system is sequential (without potential for parallel activities) there would appear to be an incremental increase in work activity in dealing with long lists of medications that might be detrimental to patient care (e.g. ten or more medications). One subject stated that “in the first part of the experiment, the patient has few records so the screen will show up in about 10 seconds, but the real patients with a long history of their admissions have lots of records so it takes a minute or more to open. It would be acceptable if we had only one patient, but in real case we have 10 or more patients so I think this process is really burdensome for us”.

4.4. System Response Time

It was noted by some subjects (during the interviews) that system response time might become a problem, with patients having long histories requiring longer for the information needed to appear on the screen. From the observational data it appeared this could be compounded by situations with multiple patients requiring complex combinations of medications. One subject stated that “I have to access many screens, which takes more time”.

4.5. System Lock

It was noted by one subject that during occasions when another health professional may be accessing the patient’s record that they would become locked out of that record (i.e. inability to access medication information when the patient’s record is completely “locked out” by other users of the system who are accessing the system at the same time).

4.6. Potential Need for System Override

Several subjects commented that under circumstance of increased work activity, complex medication administrations and emergency conditions (as described above)
that there might be the need for a way to override the lock-step sequencing of activities required by the system under emergency conditions.

5. Discussion

In this paper we have described our work in applying a simulation approach to evaluating the impact of a new health information system upon clinician workflow. This was based on analysis of user interactions involving a range of routine and atypical clinical tasks. The approach builds on previous work in the area of simulation [3] as well as usability testing [2] and led to collection of a rich set of observational and interview data. It should be noted that although the simulation could be considered “high fidelity” (in that it was highly realistic, being conducted within a real environment) the cost of running the study was minimal with recording equipment costing under $1000 Canadian dollars and analysis costs under $2000 Canadian dollars.

The study found that in addition to identifying potential sources of specific problems that would arise from implementation of the new system, it was observed that introduction of the computer would likely lead to a major change in the process of medication administration. It should be noted that this was discovered prior to widespread implementation of the system and based on the results of this study the hospital informatics staff were able to fine-tune and customize the system to minimize the problems. Using realistic clinical simulations, such as the one described in this paper, to assess both intended and unintended consequences of introduction of information technology is urgently needed in healthcare in order to reduce possibility of error and increase both user acceptance and satisfaction with systems [8-9].

Knowing the impact of systems before they are released can also greatly inform system modifications and customization as well as preparing organizations about what to expect prior to widespread system implementation.

References