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Emerging Approaches to Usability Evaluation of Health Information Systems: Towards In-Situ Analysis of Complex Healthcare Systems and Environments

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Abstract. The effective evaluation of health information technology (HIT) is currently a major challenge. It is essential that applications we develop are usable, meet user information needs and are shown to be safe. Furthermore, to provide appropriate feedback to designers of systems new methods for both formative and summative evaluation are needed as applications become more complex and distributed. To ensure system usability a variety of methods have emerged from the area of usability engineering that have been adapted to healthcare. The authors have applied methods of usability engineering, working with hospitals and other healthcare organizations designing and evaluating a range of HIT applications. We describe how our approach to doing portable low-cost usability testing has evolved to the use of clinical simulations conducted in-situ, within real hospital and clinical units to rapidly evaluate the usability and safety of healthcare information systems both before and after system release. We discuss how this approach was extended to development of methods for conducting in-situ clinical simulations in a range of clinical settings.

Keywords: human computer interaction, usability, usability testing, in-situ

1. Introduction

A wide variety of health information technology (HIT) has appeared ranging from wireless hand-held applications to Web-based patient record systems. Although innovations in HIT have the potential to dramatically improve and streamline health care, there are a number of critical problems and issues related to their successful implementation and acceptance by end users and consumers. One of the main areas of concern revolves around the following question: how can we ensure the applications that we develop are usable, meet user information and workflow needs and are safe? The design of HIT applications that are intuitive to use and that support human information processing is essential. This has become increasingly recognized as being

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critical as more and more complex software and hardware applications appear in healthcare. Usability is a measure of how effective, efficient and enjoyable a system is to use [1]. Closely related to issues of usability are issues of software safety and workflow, with the need to ensure that new devices and software increase patient safety and that workflow can be carried out in an effective and efficient manner. Methods from usability engineering have been applied to improve the usability of systems. This includes usability inspection methods, involving analysis of a user interface by an expert to identify usability problems, and usability testing, which involves observing representative users of a system carrying out representative tasks.

The importance of usability testing in healthcare has been increasingly recognized. However, the issue of how to best test and evaluate systems so that the results are both ecologically valid and generalizable to real complex clinical settings has remained to be resolved. This paper describes our work in the evolution of approaches to the evaluation of the use and usability of HIT applications, given the widespread increase in both usage and complexity of environments in which they are deployed. This paper begins with a discussion of the development of a low-cost portable usability approach that has been taken into the field to conduct studies of end users of applications in real naturalistic settings. The approach has been used to evaluate a variety of applications and devices ranging from electronic medical records (EMRs) to Web-based information resources designed for both health care professionals and lay persons [2]. We then follow this with a discussion of our most recent work in extending the concept of usability testing to conducting more realistic and ecologically valid studies involving clinical simulations conducted "in-situ" - i.e. in real clinical settings where information technology is or will be deployed.

In the early stages of our work and early experimentation with usability engineering in healthcare, we employed a number of different approaches to conducting usability testing including setting up a "fixed" usability laboratory setting. However, our experience has indicated that since this approach did not allow for collection of data at the site where the software under study is actually installed, conclusions made about a system's usability and the generalizability of findings and predictions varied in their accuracy. In addition, for many of our studies it is essential that we conduct them in the actual environment in which they are being used, in order to determine how aspects of a particular environment may be affected by interacting technologies (e.g. imaging or bar-coding technologies) and how users interact with a system in a real setting, which is not realistically possible without employing a portable in-situ approach. With the advent of inexpensive screen recording software and high quality portable digital video cameras, the costs have decreased for conducting such studies along with an increase in the portability of the equipment such that it can be taken into any hospital or clinical environment, thereby simplifying the process.

Figure 1 illustrates a continuum of approaches we have developed to guide design of usability studies. Our initial projects were mainly located on the far left side of the continuum in that they involved laboratory usability testing of systems taken out of their "natural" environment. This progressed to the development of more elaborate and realistic usability testing environments and study designs, which have previously been termed "clinical simulations" [3], however they were typically still conducted within a laboratory environment. In recent years we have moved many of our studies out of the laboratory and located both simulation studies and naturalistic studies within real-world environments (e.g. clinical settings). As indicated in Figure 1, in-situ studies may

consist of simulations taking place in a real setting (e.g. a hospital room or operating room off hours) or they may involve naturalistic recording of real healthcare activities.

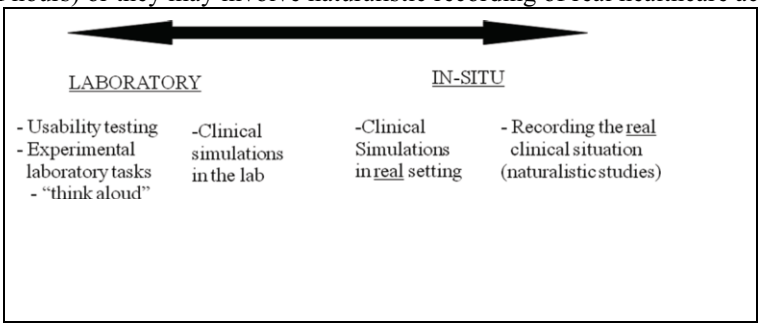

Figure1. A continuum of usability/simulation studies and settings.

2. An In-Situ Approach for Evaluating HIT Applications

In this section of the paper we will describe the set-up of in-situ usability testing that can be taken into any type of setting, ranging from the clinical (e.g. hospital rooms) to the home setting (e.g. to study use of e-health applications by patients and providers). This set-up has so far been used for a number of projects, ranging from the study of nurse's information needs to its use in the evaluation of a new medication order entry system (using bar-coding technology) prior to its deployment in a hospital in Japan [3] as well as the study of an introduction of an EMR at major American medical center, involving in-situ testing both before and after system go-live.

Our typical studies carried out in naturalistic clinical settings involve asking subjects (e.g. nurses or physicians) to interact with systems to carry out real tasks (in some studies subjects may also be asked to "think aloud" while carrying out the task, which is audio recorded). The subject's overt physical activities are recorded using one or more low-cost digital cameras (and ceiling mounted cameras where required). In addition to recording physical activities and audio of think aloud, the actual computer screens are also recorded as a digital movie file, with the audio portion of the movie corresponding to subject's verbalizations. In order to do this we are currently using a freely available software product called Hypercam©. This type of inexpensive (or free) screen recording software allows one to record all the computer screens as a user interacts with the system under study, and stores the resultant digital movie for later playback and in-depth analysis of the interaction.

The equipment we have used for many of our usability studies of HIT applications is both low-cost and portable. This typically includes: (1) one or more computers to run the software under study on, (2) screen recording software which allows the computer screens to be recorded as movie files (with audio input of subject's "thinking aloud" captured using a standard microphone plugged into the computer), (3) one or more external digital cameras to video record user's physical interactions. In studies being conducted remotely, the equipment may also include a Webcam attached to the computer that the user is interacting with. The studies we have conducted using this equipment have been carried out in a range of settings.

The total cost of the equipment is minimal (i.e. under $1,500 US). It should be noted that data collected using this combination of recording methods (i.e. screen plus

video recordings of users' physical interactions) can provide for very high fidelity recordings of user interactions, both in terms of the realism of the setting (as studies can be conducted in actual clinical settings where the application is being used in real life, leading to higher fidelity testing than is possible in a laboratory study) and higher quality recordings (with advances in low-cost digital recording).

3. Analysis of Data Collected

The analysis of the data collected (e.g. screens of user interactions, video recordings of users' problems) varies from informal analysis, which consists of simply playing back the movies of user interactions to identifying particular usability problems (e.g. where a user is unable to carry out a requested task) in the presence of designers, hospital staff, managers etc. The analysis can also involve video annotation of the movie file using software such as Transana© (a freeware video annotation program that allows analysts to "mark up" and time stamp movies of user interactions with a system) as described in Kushniruk and Patel [2]. The typical result of carrying out a usability test includes identification of specific usability problems (often in a meeting setting with system developers, customers, and hospital or management staff present). The intent of our work is typically to provide rapid feedback about system usability to provide useful information to improve system design, deployment, or customization in an efficient and rapid manner. Our most recent projects have involved applying usability engineering methods (including our low-cost portable approach) to identifying potential errors that may be caused by a system (e.g. inappropriate medication defaults in an order entry system), or "induced" by poor user interface design [4].

4. Experiences to Date

We have carried out a number of studies at varied locations (e.g. Mt. Sinai Medical Center, New York and Tottori University Hospital, Japan). Some of our earliest work involved usability testing of a patient record system at a major US medical center where the methods described in this paper resulted in a ten-fold decrease in the number of problems encountered by users of an electronic patient record system. The data analysis was conducted in a cost-effective (under $3,000 US) and efficient manner with specific recommendations for system improvement being incorporated in an improved system within several hours to weeks from the time of data collection [5]. Usability problems related to issues such as lack of interface consistency, problems in representing time sequences and issues in matching user specified terms to computer terms were identified. We have also employed a similar approach to detecting and correcting potential user problems and preventing medical error in a range of systems [4]. More recently, we have employed the method to determine how medical workflow may be inadvertently affected by the introduction of a medication order entry system [3]. In one study, which was conducted in the actual clinical setting where a new medication order entry system was deployed, subjects (nurses and doctors) were video-recorded while they interacted with both the computer system under study and patients in order to administer and record medications given to the patient. This study was conducted as a clinical simulation in-situ (i.e. in a real hospital room) just prior to system deployment. The results from such study have been used to identify not only

problems with user interfaces but also to assess how the new electronic application affected workflow and patient care. In this study, for example, it was found from an analysis of the video recordings that the introduction of the computer system would negatively affect the workflow by making it rigid and sequential (through the prescribed order of steps imposed by the medication order entry system) as compared to the typical workflow implemented prior to the introduction of a system. In some of the simulation cases (e.g. under emergency conditions) this very prescriptive workflow posed a safety challenge (e.g. particularly when users have to deal with patient emergencies) and hence recommendations were made for providing an override capability under such conditions prior to widespread system rollout. In a current extension of this approach we are applying the method to examine the impact of clinical best practice guidelines on physician workflow using an electronic medical record system at a major American hospital center. This is involving both in-situ testing of users interacting with the guidelines both (prior to widespread release) as well as naturalistic testing of the system after deployment for use with real patients (using the same unobtrusive recording technology and set up in both cases).

5. Discussion

In-situ approaches can be used to not only conduct simulations pre-implementation but also allow for post system release recording of real naturalistic interactions with systems in "live" use. Hence predictions made from in-situ studies can be tested as the system goes live (by keeping the recording equipment already in place going). Other advantages include its low cost in terms of equipment. Furthermore, by locating the studies within the actual organization where a system is going to be used, we are able to obtain direct access to a range of representative subjects and gain an improved understanding of the impact of local organizational issues and factors upon usability and safety. The impact of interfacing technologies in the real setting can also be identified. Challenges include obtaining permission to conduct studies in a real environment and issues regarding obtaining rooms and locations after hours for simulation testing. However, it is argued that if we are to ensure that the results of usability testing apply to real-world settings these types of studies are necessary.

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