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A heuristic usability evaluation of a computerized provider order entry (CPOE) technology

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Abstract

Several studies have identified usability problems with CPOE. We performed a heuristic evaluation of a CPOE technology implemented in an academic hospital. User interface design features of this CPOE technology were evaluated against a variety of widely accepted usability heuristics and user interface design guidelines. The severity of the problems and redesign priority for each problem were also evaluated. In addition, we shared and discussed our redesign recommendations with the CPOE development team. Our collaborative effort identified opportunities to improve user interface design and led to a follow-up usability testing that is being integrated into the CPOE redesign process.

Keywords: usability, CPOE, heuristic evaluation, software ergonomics, healthcare

1. Introduction

1.1. Usability of CPOE technology

Computerized Provider Order Entry (CPOE) technology is transforming health care systems. A CPOE technology is used by many healthcare providers, e.g. physicians, nurses, and pharmacists. CPOE users may need to go through complex procedures in order to achieve a task related to a particular order. This complexity can result in errors that can contribute to medical errors. Prior studies have identified several usability issues and problems of CPOE technology [1, 2]. Koppel et al. [1] identified 22 types of medication error that can by facilitated by using a CPOE technology; some of these errors are related to poor CPOE usability. For example, the CPOE technology displayed feedback on allergies after the medication was ordered. Shulman et al. [2] found that CPOE technology (without clinical decision support features) can introduce new types of errors in the medication order phase. For example, a fatal overdose can occur if users choose a dose of 7 mg/kg instead of 7 mg from the drop-down menus of the CPOE interface.

Poor usability can reduce acceptance of CPOE technology, and possibly limit its effective use and create conditions favorable for errors. Design for usability should be emphasized in the development of CPOE technology. If the CPOE technology provides error prevention and protection functions, it can certainly lower the likelihood of errors by users.

1.2. User-centered design and heuristic evaluation

Usability refers to the extent to which users can use a technology to achieve task goals effectively, efficiently, and satisfactorily. Nielsen [3] defined five attributes of usability: *ease of learning*, *efficiency of use*, *memorability*, *error prevention and protection*, and *satisfaction*. Confusion and frustration with a technology interface are sufficient to interfere with user acceptance of technology, subsequently presenting an obstacle to successful technology implementation. Therefore, a well-designed user interface is as important as functionality and reliability of the technology [4].

A highly usable CPOE technology can positively influence acceptance and use of the new technology. For example, if the system features are easy to remember, casual users (e.g., physicians who move between CPOE and non-CPOE environments) are able to return to productive use of the technology without extensive retraining.

The need for user-centered design has been increasingly emphasized. User research methods (e.g., surveys, interviews, task analysis), usability testing methods (e.g., testing of prototype with end users), and usability inspection methods (e.g., evaluation of interface design by a usability specialist) have been developed in order to implement user-centered design principles. As a usability inspection method, heuristic evaluation assesses whether the user interface conforms to widely accepted usability heuristics, user interface design guidelines, standards, and rules of thumb [5]. To perform a heuristic evaluation, several usability specialists independently judge whether design features violate the heuristics. They detect possible design problems and specify the severity of each problem (e.g., frequency, impact). Their findings are then summarized to provide an overview of the general functionality and effectiveness of the user interface design as well as a list of specific usability problems and recommendations. While heuristic evaluations are often sufficient to identify serious design problems, they may also serve as a bridge toward more formal usability testing to assess user performance [5].

Previous studies have used various user-centered design methods, including heuristic evaluation, to evaluate the usability of CPOE technology [1,2,6]. A study by Beuscart-Zephir and her colleagues [6] examined user experience with medication administration through CPOE. The following methods were used: semi-structured and structured user interviews, field observations, document analysis, heuristic evaluations, and usability testing. Usability problems were identified, such as the wrong color (gray) used for highlighting fields, although "grayed out" is usually the way to indicate "no entry" or "no modification". Users had to scroll down a long list of pre-set schedules because only 8 out of 22 items were immediately visible. To deal with these design problems, researchers suggested the use of a different highlight color and redesign of the long list to improve immediate display [6].

1.3. Present study

In this study, we performed a heuristic evaluation of a CPOE technology that is being implemented in an academic hospital. Our focus was to identify the "look and feel" user interface design problems. Usability problems associated with interactive user tasks were not examined in this study. The goal was to provide insights into usability problems that CPOE users could experience, and to integrate human factors knowledge into the CPOE design and improvement process.

2. Methods

2.1. CPOE system

The CPOE technology assessed in this study is an extensive customization of the Siemens CPOE solution implemented in an academic hospital. The hospital Information Systems (IS) department is responsible for customizing and implementing the CPOE system. The project team consists of IS analysts, programmers, quality assurance testers, trainers, clinical informatics personnel, and a project manager. The IS CPOE team strives to maintain system reliability and software quality primarily through quality assurance testing that involves clinical informaticists and technical staff. The developers performed limited testing with end users but had not previously engaged in formal usability inspections or usability testing.

The CPOE technology has been implemented in three clinical areas in the hospital: rehabilitation, medicine, and a care initiation unit. These units implemented CPOE in a serial rollout beginning February 2004. These initial implementations led to significant and ongoing system redesign based on user feedback from representative clinical groups.

The CPOE technology has a web-based user interface with secure access to the global inpatient clinical information system. The heuristic usability evaluation was limited to the inspection of several primary functional areas of the CPOE interface: the login screen, the patient profile page, and screen sequences related to medication and laboratory orders.

2.2. Usability evaluators

Two researchers performed the heuristic evaluation. One researcher (QL) was a post-doctoral fellow with academic background in human factors psychology and consulting experience in user interface design and usability evaluation. The second researcher (SD) has academic backgrounds in nursing and human factors engineering with professional experience that included clinical experience as well as web design, information architecture, and the design of media delivered continuing education. Both researchers are familiar with software design cycles, user interface design principles and guidelines, and widely accepted usability heuristics. The third and fourth co-author a (PC, ASH) reviewed and approved the evaluation plan based on their experience evaluating technology implementation and health information systems.

2.3. Procedure

Before proceeding with the evaluation, the two researchers received a series of static color screen shots in order to become familiar with the CPOE technology. A sample screen shot is shown in Figure 1. We used "TOP", "LEFT", and "RIGHT" to label the three functional regions on the screen as a means to locate the user interface objects.

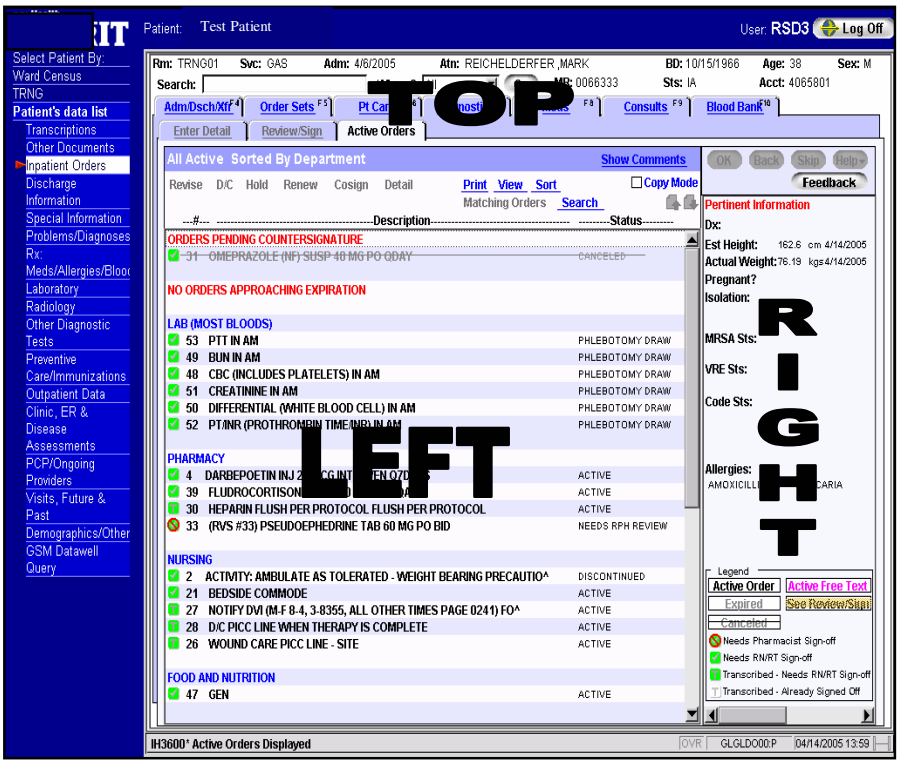
The evaluators were then invited by the CPOE development team to participate in a live demonstration of CPOE. The lead software developer presented a walkthrough of the CPOE technology and answered questions concerning available interface functions and features. The explanations and clarifications provided by the lead software developer helped the evaluators obtain a conceptual model of the system design as well as the user tasks being supported by the technology.

After meeting with the lead software developer, the evaluators carefully examined the functionality and usability of user interface objects based on the seven evaluation criteria (see 2.4.) used to report usability problems. Finally, the evaluators wrote technical reports that described the usability problems and listed recommendations. The reports were then shared with the CPOE development team.

2.4. Evaluation criteria for CPOE usability problems

Our heuristic evaluation included the development of a framework for analyzing specific usability problems. Based on Nielsen's definition that a usability problem is defined by its severity and the heuristic

Figure 1: Screen shot with window regions labeled.



principle it violates [5], we introduced seven evaluation criteria for defining a usability problem. Then we specified the coding and scoring systems for these criteria. For example, a usability problem with "high" severity indicated that users were unable to accomplish the task. Below is the list of the seven evaluation criteria:

1. Problem description
2. Problem domain (aesthetics, information architecture, navigation)
3. Location on screen: TOP, LEFT, and RIGHT
4. Potential risk for patient care
   - Low: Moderate event
   - Medium: Major event
   - High: Catastrophic event
5. Severity of problems to users
   - Low: Users take longer than necessary to accomplish task; may feel annoyed.
   - Medium: Users can accomplish task with difficulty, through trial and error; may feel frustrated.
   - High: Users are unable to accomplish task; outcome could be failure.
6. Priority to redesign
   - Low: This problem should be fixed when resources are available.
   - Medium: This problem should be fixed.
   - High: This problem must be fixed.
7. Redesign recommendations

2.5. CPOE usability problems

The evaluators provided a general evaluation of the CPOE user interface design and then identified specific usability problems. A summary of five identified usability problems is shown in Table 1.

Overall, the evaluators found that, across the user interface, most information is conveyed through text-based windows designed to represent a tabbed clinical record. There is a multi-framed, layered window effect that occurs as end users make selections from the tabbed menu structure. The windows appear stacked with the active window foremost in view. This multidimensional view offers a plethora of choices to the user. A disadvantage of this strategy is that the view is somewhat overwhelming given the density of the text and the variety of windows and menus presented to the user at one time. A fundamental concern with this presentation is that users may suffer from information overload that can impair decision making [7]. Too much information dilutes system cues that otherwise

Table 1. Summary of heuristic evaluation

*	*Usability Problem 1*
1.	Four control buttons in the RIGHT yet controlled information is in the LEFT. This design does not follow a fundamental design principle that typically places control buttons in closer proximity to the object they affect. It is counterintuitive to venture outside the active window to select objects within it.
2.	Look and feel, information architecture
3.	LEFT and RIGHT
4.	Low
5.	High
6.	High
7.	Place the control buttons within the LEFT portion.
*	*Usability Problem 2*
1.	Direction of scroll bars in the LEFT and RIGHT portions are not consistent. It is possible that some users may have difficulty in switching between vertical and horizontal scrolling. Since the vertical scrolling in the LEFT appears to have a dominant effect, it is possible that some users may not notice the scrolling option in the RIGHT and could miss important information in the RIGHT portion.
2.	Navigation
3.	LEFT and RIGHT
4.	High
5.	Medium
6.	High
7.	Change orientation of left-right scroll bar in the RIGHT portion to up-down.
*	*Usability Problem 3*
1.	The presence of two SEARCH fields on one screen may be another source of confusion for users. It is not apparent which "level" of CPOE these search functions pertain to. One of the search fields is followed by a "Where?" field, which seemingly narrows the domain of this search. However, no description or cues are offered. It is only through trial and error that users will discover the logic supporting the use of the two SEARCH Functions.
2.	Look and feel, information architecture
3.	TOP and LEFT
4.	Low
5.	Medium
6.	Low
7.	Relabel search boxes based on their functions.

Table 1. Summary of heuristic evaluation (Continued)

*	*Usability Problem 4*
1.	Icon design lacks “affordance”. For example, a green check mark indicates "Needs RN/RT signoff". This icon would intuitively suggest a completed task with no further action needed.
2.	Look and feel, information architecture
3.	RIGHT
4.	Medium
5.	Low
6.	Medium
7.	Use conventional icon color and design to indicate order status; limit use of red to high priority or emergency situations.
*	*Usability Problem 5 (see figure 2)*
1.	Patient information on the TOP portion is not well organized. This could cause the problem associated with information overloading. Patient name is difficult to see in the upper left of the screen both because it is not present in the active window and it is obscured in the dark blue border. The size and color contrast are not sufficient to enable quick reference. Furthermore, once the patient name is located, it is separated by the window frame from additional information pertaining to this patient such as the physician, service, admission date, etc. This additional information is located across the TOP and RIGHT portions. Spreading related patient information across two portions makes scanning difficult, presumably a frequent activity for physicians while making prescribing decisions.
2.	Look and feel, information architecture
3.	TOP
4.	Low
5.	Low
6.	Medium
7.	To visually group patient information on the TOP.

* 1. Problem description, 2. Problem domain, 3. Location on screen, 4. Potential risk for patient care, 5. Severity of problems to users, 6. Priority to redesign, 7. Redesign recommendations

enable users to establish a sense of location, identify navigational links, and determine system status.

The dominant color scheme of window borders, menu options, header titles, and content consists of a monochromatic layout of blue and gray. Some active menu options are underlined in a fashion reminiscent of web page hypertext. Other menu options are not underlined but appear as light gray text that is also used in the page content. A few select controls appear as gray, graphical buttons and are located outside the predominant active window. Because the general impression of the color scheme is monotonous, it requires effort to understand. The scheme is disrupted by occasional use of red text, which is utilized in several locations as section headers. Because red is traditionally reserved for warnings and system messages, this unconventional color choice places additional cognitive burden on users to understand that the header colors do not signify a problematic state but are merely an effort to distinguish separate sections.

3. Discussion

The heuristic usability evaluation we performed was effective for quickly identifying potential user interface design problems. Our findings were well accepted by the hospital IS staff. The CPOE development team promptly responded by accepting many of our recommendations. For example, they changed the label of the “search button” and the “search link” to provide better distinction between the two different search functions on the same screen. In addition, they were able to explain the difficulty of fully addressing some of the usability problems we identified as well as some of their design restrictions.

The heuristic usability evaluation appeared to be a good method for quickly and inexpensively identifying usability problems. Furthermore, the method is easily understood and served to foster recognition of the importance of usability. However, when examining a highly domain-specific user interface like the CPOE technology, a heuristic evaluation is not sufficient: it should be combined with other usability testing methods to identify problems that might be overlooked by usability specialists due to lack of domain knowledge [5]. Therefore, it is important to conduct usability testing with end users of the CPOE technology. Incorporating a think-aloud protocol during user testing would also be helpful to gather information about users’ mental models while they perform specific tasks with the CPOE technology. The think-aloud method could be combined with screen capture software to record users’ task flows during the usability testing. These tools can allow usability specialists and developers to monitor users’ activities while simultaneously gaining some understanding of their goals and intentions.

In our larger study on CPOE evaluation and implementation, our recommendations have been well accepted by the CPOE development team. We have further developed a collaborative process to improve usability of the CPOE technology: a usability evaluation plan has been developed and testing with users has begun.

4. Conclusion

The present study was a successful experience of introducing usability methods into CPOE technology redesign and improvement process. The heuristic evaluation not only identified several usability problems with the CPOE technology, but also increased the awareness of usability issues for the CPOE development team.

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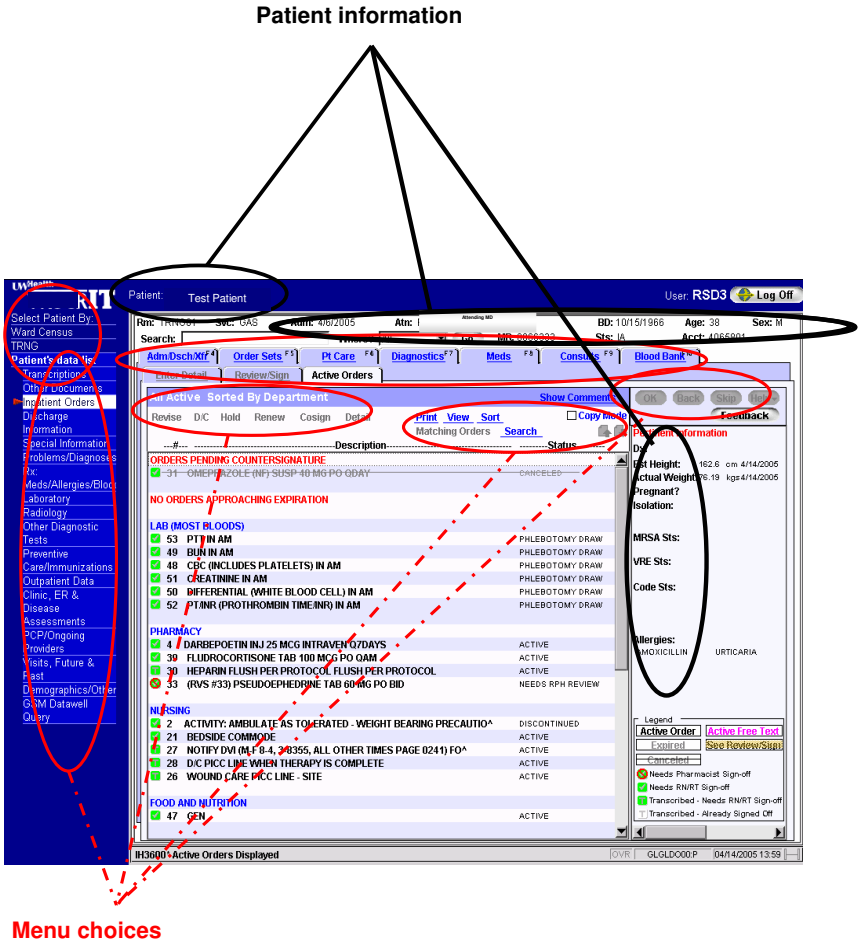
Figure 2: Illustration of Usability Problem 5