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Usability Evaluation of a Computerized Physician Order Entry for Medication Ordering

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Abstract. Despite CPOE (Computerized Physician Order Entry) systems' potential to enhance patient safety by reducing medication errors, recent studies have cast some doubts on their role in error reduction. CPOE systems with poorly designed interfaces have proven to cause users dissatisfaction and to introduce new kind of errors in the ordering process, suggesting a threat instead of an enhancement of patient safety. The main objective of this study is to identify usability problems related to a CPOE medication system's design and determining their severities. Two experts completed a cognitive walkthrough (CW) of an ordering task based on a clinical scenario for ordering the consolidation phase of chemotherapy for a leukemic patient. Fifty five usability problems were found and classified into eleven categories. CW identified cosmetic to catastrophic problems leading to inefficient use of the CPOE system and potentially resulting in users' confusion, longer ordering duration, and medication errors. The complexity of the CPOE design, its rigidness and lack of user guidance suggests the necessity to redesign the current user interface in order to match clinicians' ordering behaviors and to fully support them in the medication ordering process.

Keywords. CPOE, medication systems, medication errors, usability evaluation, assessment-evaluation, user-computer interface

1. Introduction

Computerized Physician Order Entry (CPOE) systems have potential to enhance patient safety by reducing errors in ordering medications [1–3].These systems support clinicians by alerting medication interactions, reminding them of tasks to be undertaken, checking for inappropriate orders, and suggesting recommended medication dosages and frequencies. Despite CPOE systems' potential to reduce medication errors, other studies [4–6] have revealed that some CPOE systems introduce new kind of errors in ordering process, and cause users' dissatisfaction and ordering prolongation. Introduction of a CPOE offers new functionality, but often poor user-friendliness and usability of CPOE interfaces impose heavy cognitive demands on its users [7–9], leading to users' frustration, reluctance to use the system, and medication ordering and

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administration errors due to physician-nurse miscommunications [10], suggesting a threat instead of an enhancement of patient safety.

In the Netherlands in a large academic medical center (AMC) where a hospital-wide CPOE system for medication ordering (Medicator) is implemented, complaints posed by end users drew attention to potential usability flaws in the interface of Medicator. Because of the complexity of scheduling chemotherapy and ordering cytostatic medication, end users' problems using the system, were more prominent in ordering these medications. Errors in calculating the dosage of cytostatic medications or discontinuation of cytostatic medication therapy have severe consequences for patients. Furthermore scheduling cytostatic medication therapy is a complex process and necessitates fully support of the clinician by the CPOE medication system. It was for these reasons that we focused on the usability assessment of Medicator for ordering and scheduling chemotherapy. The main objective of this study is answering the following questions: what kinds of usability problems are related to the user interface of the CPOE medication system in the AMC? And how severe are the problems found?

2. Methods

Two investigators, experts in usability evaluation, evaluated the usability of Medicator by a cognitive walkthrough (CW) while performing an ordering task. They stepped through the system based on a clinical scenario for ordering the consolidation phase of chemotherapy to a leukemic patient admitted to the Hematology department. The scenario was designed by an expert in implementation of clinical protocols and validated by the head of the Hematology department. One expert first provided a framework of actions sequences and system responses of all steps that a potential user should follow to prescribe the consolidation phase of the treatment. Then both experts evaluated the system by analyzing execution of every action and resulting system state for usability problems. Problems were categorized by two evaluators independently and coded based on this framework of actions sequences and system responses. Final decision about categories and the assignment of usability problems to each category was made by both evaluators (agreement 87%). Any disagreements were resolved through discussion. We assigned severity ratings [11] to problems based on: frequency that they may occur; the proportion of users that may encounter them, potential contribution to medication errors, potential impact on a user the first time of occurrence and the later encounters.

3. Results

The framework for ordering consolidation phase of chemotherapy with Medicator entailed 4 tasks, 9 subtasks and a total of 66 associated actions to be taken by a user. The in-depth CW analysis of the Medicator user interface revealed 56 cosmetic to catastrophic usability problems associated with the execution of the 66 actions, to potentially be encountered by end-users in real practice. Fifteen of these problems were recurring. Among the identified usability problems 17 could lead to user confusion and frustration, 15 to prolonged medication orders, five to miscommunication and increasing phone calls from pharmacy and nurses and 14 to medication errors. Severity rating of problems resulted in seven cosmetic, 31 minor, 13 major and five catastrophic problems. We categorized problems into eleven categories of which seven categories include the major and catastrophic usability problems (Figure 1). We report on these seven categories and provide examples of major and catastrophic problems identified.

Unexpected system response: At certain occasions, the CW evaluators encountered system states and responses not to be expected in response to the previous action performed. This sort of responses will cause user confusion in linking the action to the resulting system state, are very time consuming and even could lead to medication errors. CW analysts encountered three usability catastrophes related to unexpected system responses: e.g., irrespective of start time and date entered for a medication, start time for administration of medication in the "dosage table" of the system is set on 8:00. This problem requires pharmacy intervention and telephone calls to the ordering physician to be fixed; otherwise it increases the risk of lower medication administration periods and even of patients missing certain single dose medications.

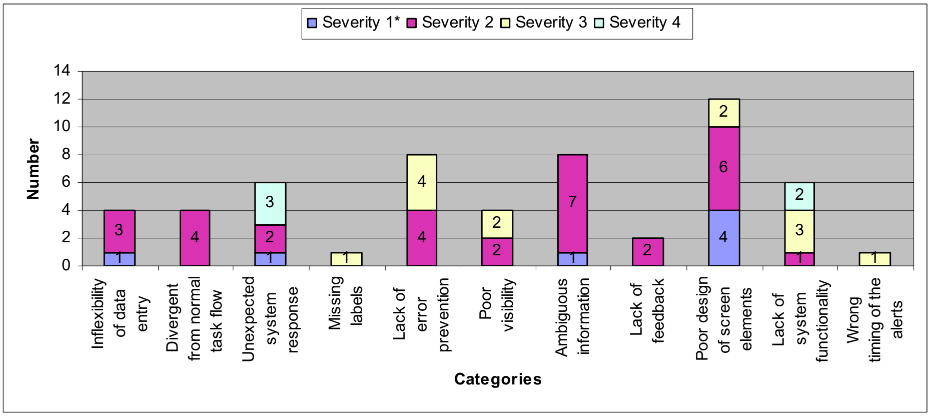
Missing labels: The absence of label indicating the unit of (an automated) dosage calculation (per day or per time of administration), in the "dosage calculation" window is a major problem that could lead to uncertainty about the total medication dosage and may result in wrong medication dosages.

Lack of error prevention functionalities: Four major problems were identified related to lack of checks and warnings concerning nonconformity and incorrectness of data entered, which could result in increasing telephone calls from the pharmacy and medication errors. For instance, lack of system's checks on "medication route" might cause wrong medication route selections, if a physician would inadvertently select a route not appropriate for the medication prescribed.

Poor visibility: Two major problems were identified concerning poor visibility of screen elements such as tabs and buttons potentially leading to user confusion, time delays, wrong medication dosages, and a rise in telephone calls from pharmacy. A major problem is that physicians may not notice the buttons "m^2" and "kg" for calculation of medication dose because of the poor visibility and closeness of these buttons. Thus physicians would resort to time-consuming calculations of dosage which may provoke medication dosage errors.

Poor design of screen elements: Poor design of functional keys, screen buttons, data entry fields, lists, and information screens in the system would potentially contribute to user frustration, inefficient searches to initiate an action, time delays and wrong item selections. Two major problems were found. A major problem is concerned with the alignment of the screen buttons "m^2" and "kg" distracting users from linking the function of these two buttons to the dosage entry field, causing physicians not to use these built-in functionalities of the system, and inciting wrong dosage calculations.

Lack of system functionality: Lack of functionalities that could help physicians in certain situations may cause user frustration, time delays, and wrong durations or dosages of medication. Three major and two catastrophic problems were found. An example of a major problem concerns lack of auto-complete functionality during the typing of a medication name which may cause users to engage in inefficient searches for a certain medication, particularly when they type the medication name wrongly, resulting in users feeling helpless. Lack of functionality to choose the number of days, instead of start and stop date, for medication duration, is an example of a usability catastrophe. This problem would increase physician's workload in defining the stop date for a medication because he would be forced to count the number of days from the



* Severity 1: cosmetic problem. Need not to be fixed unless extra time is available. Severity 2: minor usability problem. Fixing should be given low priority. Severity 3: major usability problem. Important to fix, so should be given high priority. Severity 4: usability catastrophe, Imperative to be fixed before product release.

Figure 1. Usability problems detected by cognitive walkthrough

start date, eliciting wrong durations of medications, especially when the start and stop dates are in different months or when the medication period is rather long.

Wrong timing of alerts: A major problem in Medicator is that the alert screen "medication dose units control" shows up too late in the ordering process which is annoying for the users and may induce the ignoring of these kinds of alerts, requiring pharmacy and nurses to call the physician to adapt the order; otherwise leading to wrong medication dosages.

4. Discussion and Conclusion

A total of 56 usability problems associated with Medicator system including 18 major and catastrophic usability problems were identified by the CW. Fifteen of these problems were recurring, increasing the severity of those problems and requiring high priority to be fixed. Apart from user confusion, inefficiencies and time delay in ordering, the identified usability flaws have the potential to result in ordering of wrong medications; and wrong medication doses, frequencies and durations. Although we did not analyze the usability tests with end users yet, these first results confirm earlier findings that CPOE systems may in fact contribute to medical errors due to misfit of their design and physicians' normal task behavior [12, 13]. However, many of the design flaws of Medicator can in fact easily be corrected, but could yet have been prevented when recommendations for system design, for example those put forward by International Standard Organization [14], would have been followed by the system designers. Others, particularly the more severe ones such as, those concerning lack of system and error prevention functionalities, and unexpected system responses, need more extensive redesign efforts and should be validated by the end user test results first. In comparison to a cognitive walkthrough, end user tests reveal significantly more problems of a severe and recurring nature than a cognitive walkthrough [15]. End user testing may reveal additional design flaws resulting from mismatches of clinicians' task flow, decision making and reasoning processes with the CPOE design. Particularly design flaws that result of an inadequate fit of the CPOE system and physicians' working patterns are presumably not all found by the cognitive walkthrough. We will therefore provide specific recommendations to the CPOE designers of the Medicator system not before we have also analyzed the interactive behavior of physicians who participated in the end user tests.

Overall speaking, a human centered design process should be followed from the beginning of the CPOE design process, requiring more investment in the earlier stages of system design. Medication errors can have a high impact on patients and can lead to significant additional costs. The application of knowledge from human factors engineering and ergonomics in the early phases of CPOE systems design seems inevitable to produce CPOE medication systems that enable clinicians to set out medication orders safely, and efficiently thereby attaining the main goal of CPOE introduction: reducing the risk of medication errors and associated costs.

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