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CPOE System Design Aspects and Their Qualitative Effect on Usability

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Abstract: Although many studies have discussed the benefits of Computerized Provider Order Entry (CPOE) systems, their configuration can have a great impact on clinicians' adoption of these systems. Poorly designed CPOE systems can lead to usability problems, users' dissatisfaction and may disrupt normal flow of clinical activities. This paper reports on a literature review focused on the identification of CPOE medication systems' design aspects that impact CPOE systems' usability and create opportunities for medication errors. Our review is based on a systematic literature search in PubMed, EMBASE and Ovid MEDLINE for relevant publications from 1986-2006. We categorized the design aspects extracted from relevant publications into six different groups: 1) timing of alerts, 2) log in/out procedures, 3) pick lists and drop down menus, 4) clues and guidelines, 5) documentation and data entry options, and 6) screen display and layout. Our review shows that the manner in which a CPOE system is configured can have a high impact on ease of system use, task behavior of clinicians in ordering drugs, and medication errors. Characterization of consequences associated with certain CPOE design aspects provides insight into how CPOE system designs can be improved to enhance physicians' adoption of these systems and their success. Recommendations are provided to enable CPOE system designers to create CPOE systems that are not only more user friendly and efficient but safer.

Keywords: CPOE, medication systems, medication errors, assessment-evaluation, design aspects, user-computer interface, usability evaluation, human factors

Introduction

Computerized Provider Order Entry (CPOE) systems can have a significant impact on the safety and quality of drug management [1;2]. The configuration of CPOE yet affects physicians' adoption and usage of these systems, making these systems often difficult to learn and complicated to use. CPOE interface design often does not conform to clinicians' decision-making and workflow processes making the

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appropriate order entry strategy not apparent to CPOE users[3]. Poor CPOE interface design and lack of usability facilitates medical error and may even lead to disaster if critical information is not presented in an effective manner. Both quantitative and qualitative studies have highlighted examples of CPOE system design flaws that indeed lead to errors in orders. Many adverse drug events for example result from poor interface design rather than from human error [4-6]. Complex CPOE systems place heavy cognitive demands on the users and may result in suboptimal use of features designed to support clinicians in the ordering process[7;8]. Use of effective external representations could yet facilitate the completion of order entry task[7;8]. However, despite the great impact of CPOE design on usability and medical errors, no literature reviews have focused specifically on the influence that certain CPOE design aspects can have on the difficulties that clinicians encounter when using a CPOE system. The purpose of this study was to review current evidence of the impact of CPOE design aspects on clinicians' ordering behavior and opportunities for error attributable to the interaction process. We reviewed the literature for original studies describing a (usability) evaluation of CPOE systems' design aspects and report on the preliminary results. Recommendations are provided to enable CPOE system designers to create systems that are not only more user friendly and efficient but also safer.

1. Method

A systematic literature search in PubMed, EMBASE and Ovid MEDLINE of papers published from 1986-2006 was performed. These databases were searched for English-language publications with four groups of key terms related to: (1) CPOE and Electronic prescribing systems, (2) Computer and electronic, (3) Prescription and, (4) Usability and workflow. Key terms in each group were combined by operator "OR". Generally we used the following combinations in search strategies; (1 AND 4) OR (2 AND 3 AND 4) to extract relevant studies.

The authors reviewed the abstracts of the resulting papers independently. Articles were included when they described an original usability evaluation study of a CPOE medication system in health care. In case of any doubt, full texts were reviewed. Editorials, letters, and conceptual papers were excluded. Any disagreements between researchers were resolved through discussion. We clustered CPOE design aspects described in these papers into six groups as follows: 1) timing of alerts, 2) log in/out procedures, 3) pick lists and drop-down menus, 4) clues and guidelines, 5) documentation and data entry options, and 6) screen display and layout. Selection of design aspects and of their effects on CPOE systems' usability and clinicians' ordering patterns was done by both authors.

2. Results

Our search in PubMed and Ovid resulted in 724 papers published from 1986 to 2006 of which 11 papers met our inclusion criteria and were reviewed for data collection (see Table 1). Published studies [5;8;9] reported that alerts which show up too early or too late in the workflow of CPOE users ordering medication can lead to errors from which users cannot recover. Users may indeed search for alert information at a different moment in time unnecessarily hampering and prolonging the ordering process [8].

Post-hoc alerts persuaded users to shift the responsibility of drug interaction checking to the pharmacist [5]. In another study [10], failure to alert in the proper time caused deactivation of orders and prevented users to be aware of a drug-allergy interaction. Lack of timely duplicate checking when clinicians ordered a new dose of the same medication, [11] or the same medication in another form, or re-ordered medication prescribed earlier [4] resulted in duplicate medication orders, potentially leading to overdoses. Likewise, a failure to warn CPOE users that antibiotic drugs had to be preapproved caused delays in approval, and resulted in gaps in antibiotic therapy [5].

Inconvenient logging procedures, especially when the log-out takes time because of security measures, incited many physicians to order medications at computer terminals not yet "logged out" by other physicians [5;12]. As a result, physicians signed orders that they did not enter themselves. Using another clinician's logged-in session can yet result in either unintended patients receiving certain medications or patients not receiving the intended medication [5].

Picking wrong items from drop down lists and multiple choice items on the computer screen, and failure to differentiate look-alike patient names led to selection errors [7;10;11], e.g. wrong patient, a wrong drug, and wrong drug routes. Close proximity of selection items on the screen e.g. items on the drop down list for order routes may cause juxtaposition errors [9]. Lengthy lists of items in menus, with few of

Table 1. CPOE design aspects in the relevant articles

	Alerting				Log –in/ out	Drop-down lists		Clues and guidelines						Documentation and data entry components				Screen display/ layout and appearance			
Reference number	Wrong timing of alerts	Real time alerts	Failed alerts	Lack of Alert functionality	Inconvenient log-in procedures	Lengthy list of menu items	Proximate screen items	Screen icons	Lack of clues and information	Lack of explanation automated computation	Obscure order hierarchies	Poorly designed icons		Documentation templates	Data entry fields	Pre-set global schedules	Case sensitive fields	Poorly conceptualized graphical representations	Multiple screen displays of medications	Faulty screen display	Suboptimal displayed measures
3									✓												
4				✓											✓					✓	
5	✓			✓	✓														✓	✓	✓
7						✓					✓							✓		✓	
8	✓	✓								✓					✓			✓			
9	✓						✓														
10			✓			✓											✓				✓
11				✓		✓														✓	
12					✓									✓							
13						✓			✓							✓				✓	
14								✓				✓		✓							
Frequency	3	1	1	3	2	4	1	1	2	1	1	1		2	2	1	1	2	1	5	2
Total	8				2	5		6						6				10			

the items visible at once, are difficult to use [13] and require users to scroll down to see the other items [7;13].

Icons on the screen reminding users of forthcoming tasks help them to organize and time their tasks. Nurses likewise can be confused by CPOE systems displaying exact times for drug administration without providing clues as to whether these specific times are critical or not. Horsky et.al [3] found that screens providing few clues and insufficient information to support users in their natural task flow necessitates users to perform a series of demanding estimations and comparisons required to accomplish the order tasks. Although automated dose calculation facilities can assist users in deciding on a drug dose, computations that are represented without their algorithmic basis forces users to calculation which complicates the interaction [8]. Obscure hierarchical structuring of orders require novice CPOE users to involve in a prolonged trial and error task causing time delay, selection of wrong drug sets and failures to find an appropriate drug order set [7].

Banet et.al [14] reported that documentation templates prompting users to enter certain information granted efficiency and standardization of documentation e.g., use of these templates prevented double/triple charting. CPOE interaction structure relied upon a cognitive model of classifying orders which the physicians did not always share, introducing difficulty in structured data entry and prolonging this procedure[12]. The meaning of a number of fields specially adjacent ones in a data entry screen can be easily misinterpreted [4;8]. These kinds of misinterpretations can, in a positive sense generate alerts prolonging the ordering process. One study [13] showed that the use of grey boxes for highlighting preferred time-slots for drug dispensing by nurses that were to be activated by physicians were misinterpreted by the same physicians as fields in which no data could be entered. Another study [10] showed that string sensitivity of data fields ('TID' entered instead of 'T.I.D.') during ordering caused ordering failure.

Several studies [4;5;7;8;10;11;13] reported on the effects of suboptimal screen displays of medication ordering systems. Poorly conceptualized graphical representations make it difficult for CPOE users to find certain information leading to inefficient searches for information provided by the system. Poor conceptual presentation of alerts likely increase cognitive effort and require users to engage in an extensive search for this information, unnecessarily prolonging the ordering process with potential for medication errors[8]. Moreover poor display of entered orders do not allow for simple visual reviews of these orders [8], necessitating users to scroll through several screens and forcing them to rely on the history of orders in their own memory [7], which creates opportunities for medication errors. Multiple-screen displays of a patient's medications indeed prevented physicians from seeing a patient's complete medication record, with medication discontinuation and selections of wrong medications as result [5]. Huge amounts of information displayed in one screen likewise forces clinicians into a cognitively exhausting and error prone task[7]. Fragmented CPOE displays for example made it difficult for physicians to identify the patient they were actually ordering for [5;7]. Subtle differences in lay-out and appearance of screen entry forms, data labels and values yet providing important functional differences led to erroneous interpretation of stop times for drugs [4]. Moreover, lack of an explicit indication that a laboratory result was not from the same day as the day of the drug order let a clinician set out another drug order, leading to an overdose [4]. While another study found that invisibility of dates on printouts confused users who assumed that two printouts for a similar medication represented a duplicate order whereas in reality these concerned two different orders[11]. Suboptimal labeling (for example for 'package' instead of 'tablets') of medication amount [10] and displaying drug dosages according to pharmacy warehousing and purchasing decisions

rather than according to clinical guidelines [5] can lead to overdoses or medication under-dosing.

3. Discussion

The outcomes of this review shed light on design features of CPOE medication systems and concealed usability problems related to them. Owing to the characteristics of CPOE design aspects described in this paper, designers can consider them from the start point to avoid suboptimal CPOE usability. Our preliminary results show that in designing CPOE systems, the following points should be considered to avoid error-prone CPOE designs: 1- Design interfaces that explicitly map to the workflow patterns of clinicians, so as to keep the ordering process as less cognitively complex as possible. 2- Provide users by clues in the interface to optimally support them in medication ordering. These external cues in the display can fulfill a central role in controlling the CPOE user interaction. 3- Reduce the layers of screens (to a maximum of 3 layers) to facilitate users navigation in the system. This recommendation is based on insights from cognitive psychology[15], and consistent with the study results showing that for certain CPOE systems clinicians report a loss of overview when they are forced to navigate through too many different screens to review a patient's current medication status. 4- Alerts should be timed properly in order to be displayed in a timely manner; that is at the moment a clinician would himself search for this information. 5- Alerts should also be displayed in a more prominent position on the screen, so that these are more easily noticeable. 6- Use consistent terms throughout the CPOE system that are related to task. 7- Group screen elements that are related, physically together, so that the layout of these elements on the screen guide the CPOE user to the information they are looking for. 8- Organize screen-elements into logical groups, visually separated by space and alignment. 9- Give enough space to user interface items to prevent users from inadvertently clicking the wrong options. 10- Make active and passive screen elements easily distinguishable by consistent use of tick boxes and pick lists. 11- Use colors sparingly and consistently, giving important elements (e.g. alerts) prominence through contrast, making it easier for clinicians to notice information intended to arrest their attention.

In the same way, results showed that in order to have CPOE systems aligned with workflow pattern of clinicians the following designs should be avoided: 1- Deep navigational structures in order to make the user system interaction more effective. 2- Too close positioning of Screens elements. 3- Use of the same color for data entry fields and fields in which no data can be entered. 4- Long drop-down menus which require the user to scroll down. 5- Use of documentation templates classifying orders different from the cognitive model of physician ordering. 6- Use of string sensitive data fields especially for abbreviations. 7- Provision of too many alerts. To prevent alert overriding prioritize important alerts by colors. 8- The displaying of huge amount of information in one screen to avoid an exhausting and error prone task by physicians. 9- Obscure hierarchies of orders and order sets.

Since a CPOE user interface handles the communication with the end-user, thoughtful considering its design is crucial to produce a usable system.

4. Conclusion

To our knowledge up to now, this is the first review focusing exclusively on design aspects of CPOE medication systems and their potential for introducing error in the order process. Despite of our extensive search we ended up with few original usability studies about CPOE medication ordering systems indicating that more research should be done in this respect. Characterization of consequences associated with certain CPOE design aspects provides insight into how CPOE system designs can be improved to enhance physicians' adoption of these systems and their success. We ourselves will at least refer to these insights as input to a usability evaluation of the CPOE medication system of the Academic Medical Center (AMC) in the Netherlands with the ultimate aim to improve its design so as to prevent medication errors.

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