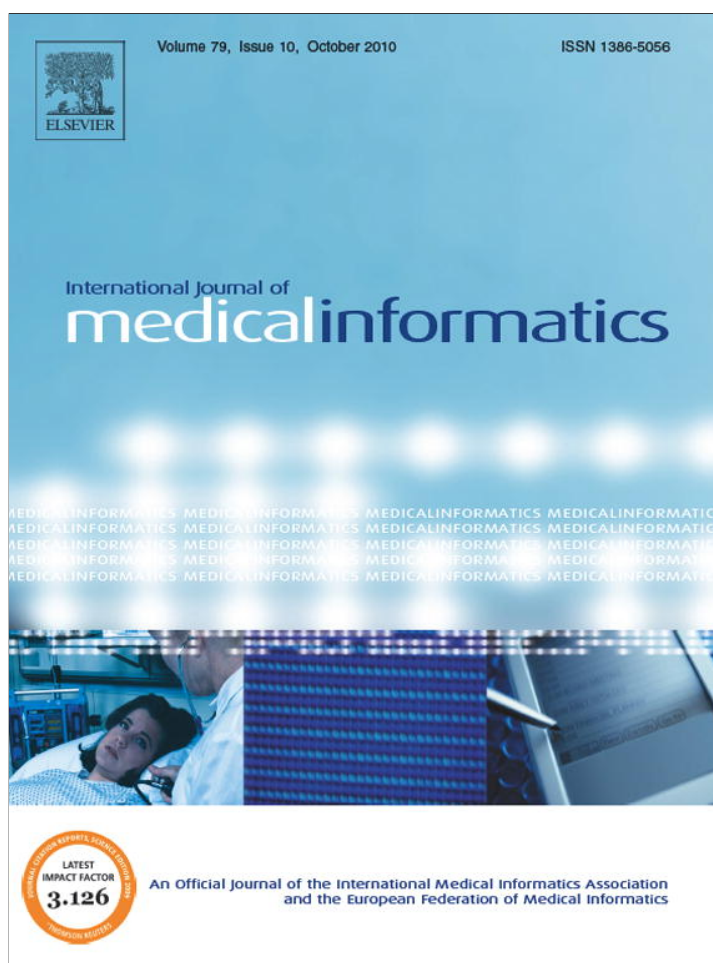


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Effect of predefined order sets and usability problems on efficiency of computerized medication ordering

R. Khajouei^{a,b,*}, N. Peek^a, P.C. Wierenga^c, M.J. Kersten^d, M.W.M. Jaspers^{a,**}

^a Department of Medical Informatics, Academic Medical Center – University of Amsterdam, The Netherlands

^b Kerman University of Medical Sciences, Kerman, Iran

^c Department of Clinical Pharmacy, Academic Medical Center – University of Amsterdam, The Netherlands

^d Department of Hematology, Academic Medical Center – University of Amsterdam, The Netherlands

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ABSTRACT

Objectives: To study the effect of predefined order sets on the efficiency of computerized medication ordering, and to analyze the effect of different types of usability problems on ordering efficiency.

Methods: Crossover study to comparing the efficiency of two methods of ordering (with and without use of predefined order sets) in a laboratory setting using a computerized physician order entry system (CPOE). The excess number of mouse clicks and keystrokes (the difference in number of mouse clicks and keystrokes needed by each physician and the minimally required numbers to accomplish the ordering tasks) for each method was measured and per physician, occurrences of usability problems during the task sessions were recorded. Observed usability problems were categorized using Zhang et al.'s heuristic principles of good user interface design. The effect of different types of usability problems on the excess number of mouse clicks and keystrokes was statistically analyzed.

Results: The median excess number of mouse clicks and keystrokes needed by physicians was 6.2 times lower in the method with predefined order sets ($p < 0.01$). The excess number of mouse clicks and keystrokes was significantly increased by vague and erroneous system messages with a factor of 2.62 (95% CI 2.24–3.07), the use of unfamiliar language and terminology by a factor of 1.28 (95% CI 1.14–1.43), and non-informative system feedback by a factor of 1.15 (95% CI 1.03–1.28), respectively. Other categories of usability problems had little influence on ordering efficiency.

Conclusions: Predefined order sets can improve the efficiency of computerized ordering by reducing the excess number of mouse clicks and keystrokes. However, the efficiency of computerized ordering can be significantly impaired by usability problems due to vague and incorrect system messages, unfamiliar language, and non-informative system feedback.

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* Corresponding author at: Department of Medical Informatics, Academic Medical Center, Meibergdreef 15, PO Box 22700, 1105 AZ Amsterdam, Noord Holland, The Netherlands. Tel.: +31 20 566 7874; fax: +31 20 691 9840.

** Corresponding author. Tel.: +31 20 566 7874; fax: +31 20 691 9840.

E-mail addresses: r.khajouei@amc.uva.nl, rkhajouei@yahoo.com (R. Khajouei), m.w.jaspers@amc.uva.nl (M.W.M. Jaspers).

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1. Introduction

Computerized physician order entry (CPOE) has been put forward to improve the medication ordering process, which is known to be a complex, time consuming and error prone task. While the use of CPOE has been shown to significantly reduce the medication turnaround times [1], the time lag from placement of order to nurse receipt [2], and the time from prescriber composition to pharmacist verification [3], there is also evidence that CPOE introduction can prolong the ordering time for physicians [4,5].

Predefined order-sets could reduce the time needed by physicians to set out orders. An order set is a group of predefined orders that is used directly by a physician to create orders for a specific patient. The use of paper-based order sets has resulted in reduction of ordering errors and improved completeness of medication orders [6,7]. Predefined order sets integrated into CPOE systems provide clinicians with evidence-based knowledge at the point of care and increase the awareness of clinical protocols and guidelines. They additionally may improve efficiency by grouping orders together, specifically when several medications related to a patient's condition or a clinical protocol are scheduled. Yet, ordering efficiency may be reduced by complex user interfaces of CPOE systems. Previous studies have shown that designs of user interfaces of certain CPOE systems do not follow the usual task behavior patterns of end users [8–10]. Moreover, it has been shown that inconsistencies in the behavior of system controls (e.g. buttons, menus and entry fields), rigid hierarchical user interfaces and suboptimal screen layout of CPOE systems can make it hard to find certain information, leading to inefficient searches and extra actions by users [10,11]. Likewise, poor conceptual presentation of alerts and poor display of medication orders can increase the cognitive effort of users, unnecessarily prolonging the ordering process. So, many of the difficulties CPOE users experience in interaction with the system are the product of the cognitive demands imposed by the interface. These problems may lead to situations during ordering requiring much effort and time of the physicians to turn these problems around or recover from them. Physicians yet often identify efficiency as the most important expected benefit of CPOE to their daily workflow [12]. Getting physicians to adopt and use specific functionalities of clinical information systems, such as CPOE integrated predefined order sets requires user interfaces that are easy and efficient to use in practice. The question is whether predefined order sets provided by CPOE systems indeed make the ordering process easier to complete, thereby enhancing ordering efficiency.

Research into the impact of CPOE predefined order sets on ordering efficiency compared to the situation in which physicians order medications one by one (single medication order) is yet lacking. Also, the effect of different types of usability problems associated with both methods of ordering on efficiency is not well studied. When the efficiency of the CPOE supported ordering process is impeded by suboptimal usability of the CPOE user interface, it is relevant to gain insight into the types of usability problems to be tackled in CPOE (re)design efforts. The human computer interface literature has put for-

ward heuristic principles that a good user interface should follow and that can be used to check the usability of a system. A modified version of these heuristics (based on [13] and [14]), called the Nielsen-Shneiderman heuristics, has been successfully used by Zhang et al. [15] to characterize different types of usability problems with medical devices.

The objectives of this study are twofold: (1) to assess physicians' efficiency of ordering by CPOE with and without predefined order sets; and (2) to analyze the effect of different types of usability problems, as defined by the Nielsen-Shneiderman heuristics, on physicians' ordering efficiency.

2. Study context

2.1. Organizational setting

This study was conducted at the Academic Medical Center (AMC), a large university hospital in Amsterdam, the Netherlands. The AMC has 21 outpatient departments, 34 inpatient departments, 5-day care units, and employs 960 full time equivalent clinicians. The AMC houses a hematology/oncology department that comprises a total of 18 beds with 560 patient admissions per year (2008). In addition, there the department has a day care facility with 12 beds and 1057 admissions in 2008. Patients with hematologic malignancies and solid tumors are admitted to this department for (high dose) chemotherapeutic treatment and/or autologous or allogeneic stem cell transplantation.

2.2. CPOE system

Medication orders in the hematology/oncology department are prescribed via a commercial CPOE medication ordering system called Medicator[®] (iSOFT, Leiden, the Netherlands), which has been in use since 2000. This system is used in 30 clinical departments of the AMC and 15 other hospitals in the Netherlands. A detailed description of Medicator is given by Kalmeijer et al. [16]. Medication ordering by Medicator can be accomplished either using predefined order sets or by prescribing single orders.

An order set is a predefined template of medications jointly belonging to a pharmacotherapeutic protocol, with default values for each medication's dosage, frequency, route of administration, and duration of treatment. Once a physician initiates an order – by instantiating an order set – related information from the template will be displayed to the physician through different windows (Protocol information, Dosage calculation, etc.). The physician has to review the information in each window and confirm it by clicking the "OK" button to order the medications.

In ordering without order sets (single orders), the physician has to order each medication one by one. To order each medication several data fields such as dosage and route should be filled out or selected from drop-down menus provided by Medicator. As soon as the physician has confirmed the order, the system checks the order for interactions. In the absence of any interaction the medication will be ordered. Otherwise the physician will be alerted on the interaction.

3. Methods

3.1. Study design

Ten physicians from the hematology/oncology department were asked to order medication by Medicator. We opted for this department because of the extensive use of medication protocols in this department and the complexity of scheduling chemotherapy and ordering cytostatic medication, requiring full support of the physicians by the Medicator system.

Participants were asked to order medications twice using the same clinical scenario, once using the predefined order sets and once without making use of these order sets. To eliminate carryover learning effects, the participants were randomly divided into two equally sized groups and introduced to the two ordering methods (with and without using order sets) in a counter-balanced design (i.e., Group 1 used order sets first, Group 2 ordered without order sets first). Participants were instructed to verbalize their thoughts while performing the ordering tasks. The ordering sessions took place at the actual work site of the physicians. Morae[®] version 2.0 (TechSmith Corporation, Okemos, Michigan), a usability evaluation tool, was used to capture video and audio tracks of the participants and of the corresponding screen sequences, changes and movements (e.g., mouse clicks and keystrokes) while the physicians were performing the tasks. We used a built-in microphone and a webcam and Morae run as a process in the background, preventing users from being distracted by the recording equipment. Participants were reminded to keep talking if they remained silent for an interval of 20 s.

3.2. Clinical scenario

The clinical scenario concerned the prescription of the first course of consolidation chemotherapy for a 19-year old patient (height = 185 cm and weight = 86 kg) with acute promyelocytic leukemia (low risk). This course of consolidation chemotherapy requires the prescription of two medications according to the Dutch adult hematology-oncology study protocol for patient with acute promyelocytic leukemia (HOVON 79): Idarubicin, 5 mg/m²/d by intravenous infusion (2–5 min) on days 1–4, and ATRA (All-trans retinoid acid, Vesanoïd[®]), 25 mg/m²/d PO (by mouth) fractionated into 2 doses on days 1–15 in patients aged <20 years. Physicians were allowed to review the protocol information using any available resources. The optimal route through the system to accomplish the ordering tasks based on this clinical scenario without predefined order sets requires 86. With predefined order sets this requires 61 mouse clicks and keystrokes.

3.3. Participants

One attending physician and nine residents out of a total of 12 residents rotating on the hematology/oncology department at the time of the study were recruited to take part in this study. The age of the participants ranged from 27 to 47 years, all had more than three years of computer experience, and working experience ranged from one to six years for residents.

The attending physician had 11 years working experience. The weekly use of Medicator at the time of the study ranged from two to eight hours for eight participants. Two of the participants used Medicator more than eight hours weekly. All participants had received an introduction of the Medicator system and hands-on training of two hours during their first month at AMC.

3.4. Outcome measures

The outcome measures defined in this study were:

- The excess number of mouse clicks and keystrokes, i.e. the difference between the number of mouse clicks and keystrokes needed by each of the participants to order medications and the required number when the optimal route through the system is followed (the minimum number). Since physicians might alternatively use mouse clicks or keystrokes for doing a same action, we added up the number of mouse clicks and keystrokes per physician per method.
- Per physician and per method of ordering, the frequency of problem occurrences concerning different categories of usability problems.

3.5. Data acquisition and data analysis

Video and audio recordings of participants' interaction with Medicator and corresponding screen recordings were played back with the Morae manager. Per method of ordering the number of mouse clicks and keystrokes of each participant was retrieved from the Morae manager. From these numbers, the minimally required number of mouse clicks and keystrokes (the number when the optimal route is followed) was subtracted. In the remaining of the paper, we refer to this as "excess number of mouse clicks and keystrokes." The Wilcoxon signed rank test was used to compare the excess number of mouse clicks and keystrokes for the two methods of ordering. The Mann-Whitney test was used to check for potential carryover effects by comparing the average number of mouse clicks and keystrokes of the two groups of participants.

Two evaluators having expertise in usability analysis reviewed and analyzed the recordings based on the method of protocol analysis [17]. The evaluators independently provided two distinct lists of usability problems that the participants came across during the experiments. Per physician and for each method of ordering, the number of occurrences of each of these problems was counted. Identified usability problems were merged into a unique list and disagreements were resolved through review of video and audio data and subsequent discussion. In a consensus meeting of three usability experts the severity of each of the usability problems was assessed based on three characteristics: frequency, impact and persistence as described by Nielsen [13], p. 104. Fig. 1 shows Nielsen's severity rating for usability problems. The Wilcoxon signed rank test was used to compare the average number of usability problem occurrences, per physician between the two ordering methods (with and without order sets). As we consider usability problems at different severity levels (cosmetic, minor, major, catastrophic) incommensu-

0 = this is not a usability problem at all
 1 = cosmetic problem only-need not be fixed unless extra time is available on project
 2 = minor usability problem-fixing this should be given low priority
 3 = major usability problem-important to fix, so should be given high priority
 4 = usability catastrophe-imperative to fix

Fig. 1 – Nielsen’s severity rating for usability problems [13].

Category	Definition
Consistency	Users should not have to wonder whether different words, situations, or actions mean the same thing. Standards and conventions in product design should be followed.
Visibility	Users should be informed about what is going on with the system through appropriate feedback and display of information.
Match	The image of the system perceived by users should match the model the users have about the system.
Minimalist	Any extraneous information is a distraction and a slow-down.
Memory	Users should not be required to memorize a lot of information to carry out tasks. Memory load reduces users’ capacity to carry out the main tasks.
Feedback	Users should be given prompt and informative feedback about their actions.
Flexibility	Users always learn and users are always different. Give users the flexibility of creating customization and shortcuts to accelerate their performance.
Message	The messages should be informative enough such that users can understand the nature of errors, learn from errors, and recover from errors.
Error	It is always better to design interfaces that prevent errors from happening in the first place.
Closure	Every task has a beginning and an end. Users should be clearly notified about the completion of a task.
Undo	Users should be allowed to recover from errors. Reversible actions also encourage exploratory learning.
Language	The language should be always presented in a form understandable by the intended users.
Control	Do not give users that impression that they are controlled by the systems.
Document	Always provide help when needed.

Fig. 2 – Nielsen-Shneiderman heuristics modified by Zhang et al. [15].

table, these numbers were compared separately for each severity level. To identify specific occurrences of user problems, two evaluators coded the usability problems based on the fourteen Nielsen-Shneiderman heuristics modified by Zhang et al. [15]. Usability problems were categorized as violations of these heuristics (Fig. 2). Disagreements concerning the assignment of the problems to these categories were resolved through discussion with a third evaluator. Whenever a usability problem seemed to be caused by a violation of multiple heuristics, it was classified under the category that was agreed upon as being most representative by all three evaluators. The recordings of the participants were further reviewed to investigate the situations in which participants came across different categories of usability problems. We used Poisson regression to analyze the effect of various categories of usability problems on the number of mouse clicks and keystrokes. Spotfire S+ 8.1 (TIBCO Software Inc., Palo Alto, California) was used to conduct all statistical analyses.

To verify that the order sets would not affect the quality and safety of medication ordering, a clinical pharmacist reviewed all medication orders (each physician ordered 2 medications per method), based on protocol HOVON 79 in order to identify possible medication errors. Subsequently, the pharmacist and a hematologist determined the potential severity of these errors for bringing harm to the patient if they would reach the patient using the NCC MERP Index for categorizing medication errors algorithm [18]. They agreed on the ratings by consensus.

4. Results

The total excess number of mouse clicks and keystrokes varied from physician to physician, ranging from 16 to 72 (median 26) in ordering with predefined order sets, whereas in ordering without order sets it ranged from 98 to 416 (median 161). As one of the physicians failed to accomplish all of the steps required in ordering medications according to the HOVON 79 protocol, the data of this participant were excluded from the analyses. Fig. 3 shows the excess number of mouse clicks and keystrokes needed by the physicians when ordering with and without order sets. The Wilcoxon signed rank test showed that

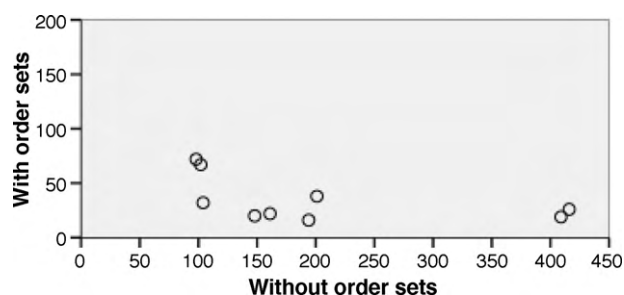


Fig. 3 – Scatter plot of the excess number of mouse clicks and keystrokes needed by the physicians in ordering with and without order sets.

Table 1 – Number of unique usability problems per severity and the average number of usability problem occurrences per physician, at each severity level.

Severity level	Number of unique usability problems		Average number of usability problem occurrences per physician		
	With order sets	Without order sets	With order sets	Without order sets	<i>p</i>
1. Cosmetic	4	0	0.44	0.00	0.046
2. Minor	15	14	6.00	5.00	0.234
3. Major	9	10	3.78	5.11	0.048
4. Catastrophic	4	4	0.67	3.11	0.007

the excess number of mouse clicks and keystrokes was significantly lower in ordering with predefined order sets ($p < 0.01$). There were no significant differences in the average number of mouse clicks and keystrokes between the two groups of participants ($p > 0.05$), indicating that carryover learning effects were small or non-existent. Thus, the number of mouse clicks and keystrokes did not depend on the order in which the methods were used.

Fifty-five unique usability problems were identified by one of the evaluators and 57 by the second evaluator. Fifty-two of these problems were shared by the two evaluators resulting in a total of 60 unique usability problems. Table 1 lists the number of unique usability problems and the average number of usability problems occurrences, per severity level and broken down by ordering method. Twenty-eight unique usability problems were revealed in the method without order sets and 32 in the method with order sets. Users most frequently came across minor usability problems (severity level 2; 5.50 times on average per medication order) without any significant difference induced by the usage of order sets. Cosmetic problems were rare (0.22 times per order) and only occurred when order sets were used. Conversely, the occurrences of major (3.78 vs. 5.11) and catastrophic (0.67 vs. 3.11) usability problems were significantly lower when ordering with order sets.

From the total number of 60 unique usability problems 53 problems were categorized similarly by both evaluators based on the Nielsen-Shneiderman heuristics modified by Zhang et al. The rest of the problems was categorized after discussion with a third reviewer. Table 2 shows the number of usability problem occurrences per method of ordering categorized as violations of these heuristics.

None of the usability problems was assigned to the categories “Memory”, and “Control”. Moreover, because of the low frequency of usability problem occurrences (0–10 occurrences in each method of ordering) in the categories “Consistency”, “Match”, “Minimalist”, “Closure”, “Undo”, and “Document”, the problems from these categories were clustered in one category (“Others”) in the analyses. Therefore, seven categories (Visibility, Feedback, Flexibility, Message, Error, Language and Other) remained for the statistical analysis. From these categories, when physicians used predefined order sets, the occurrence of usability problems in the category “Visibility” ($n = 27$) was higher than the occurrences in the other categories ($n = 6–17$ occurrences per category). In ordering without order sets, the occurrence of the problems in the category “Others” ($N = 7$) was lower than the occurrences in the other six categories ($n = 17–24$ occurrences per category).

The regression analysis (Table 3) showed that the occurrences of problems categorized under “Message,” “Language” and “Feedback” significantly increased the excess number of

mouse clicks and keystrokes in the two methods of ordering. The problems classified under “Message” were related to erroneous system messaging, insufficient content of system messages, and unclear information or guidance, precluding the physicians to understand the problem that generated the alert or how to solve the problem. The category “Language” concerned confusing terminology in labeling of buttons and use of abbreviations and expressions that were not understandable to the physicians. The problems in the “Feedback” category were related to system responses mismatching the data entered by the physician, redundant feedback, or lack of informative system feedback. In situations where Medicator provided insufficient, unclear or erroneous message contents, physicians were lost and resorted to trial-and-error behavior exemplified by the extra mouse clicks and keystrokes they

Table 2 – Number of usability problem occurrences categorized as violations of Nielsen-Shneiderman heuristics.

Violated heuristic	No. occurrences	
	With order sets	Without order sets
Consistency	2	6
Visibility	27	17
Match	1	1
Minimalist	10	0
Memory	0	0
Feedback	10	22
Flexibility	14	21
Message	17	19
Error	11	22
Closure	1	0
Undo	2	0
Language	11	24
Control	0	0
Document	1	0
Total	107	132

Table 3 – Effect of different categories of usability problems on the excess number of mouse clicks and keystrokes, estimated with multivariable Poisson regression analysis.

	Multiplication factor	95% CI
Order sets	0.49	0.35–0.69
Visibility	0.90	0.86–0.95
Feedback	1.15	1.03–1.28
Flexibility	0.98	0.85–1.14
Message	2.62	2.24–3.07
Error	0.97	0.92–1.02
Language	1.28	1.14–1.43
Others	0.78	0.70–0.87

needed for locating and executing the right action in response to the message. Likewise, physicians became frustrated when they faced information in unclear language or terminology, or when they received illogical or no system feedback on their actions. In these situations, physicians reread the information or tried to redo or cancel their actions. For example, when a physician selected a start time for administration of a medication from a drop down menu, Medicator displayed a different time based on the medication administration routines in the clinical ward. The user had no clue why this change happened and tried to redo the action by typing the time again.

There was no significant effect of the categories “Flexibility” and “Error” on the excess number of mouse clicks and keystrokes in setting out the orders. The former category concerned usability problems related to system rigidity to customize data entry facilities and to search for certain information, and the inability to open particular menus and tabs at moments that this was required in the interaction process. The latter was related to lack of system alerts and guidance to prevent incorrect actions by the user, and to lack of patient tailored checking of medication orders.

The problems categorized under “Visibility” and “Others” slightly reduced the number of mouse clicks and keystrokes. The problems classified as “Visibility” concerned poor visibility of screen buttons and tabs, invisibility of changes in system states following an action and invisibility of next actions to be taken. The category “Others” included problems related to inconsistent use of colors and labeling of medication names, large amounts of information displayed in one list, and a lack of distinction in presentation of different items (e.g. current and previous orders) and impossibility to undo an activity.

The Poisson regression analysis showed that independent of the effect of usability problems on efficiency, participants on average needed 16 more mouse clicks and keystrokes than the number required in the optimal route in ordering without order sets. In ordering with order sets, they needed eight more mouse clicks and keystrokes, on average.

Review of the ordering by the clinical pharmacist and the hematologist showed that from the 18 medication orders set out by the nine physicians who completed the ordering tasks, two (11%) orders composed with order sets and three (16%) orders composed without order sets could potentially result in harm to the patient. None of these errors could have resulted in permanent patient harm or death if they would have reached the patient.

5. Discussion

5.1. Principal findings

The results of this study show that predefined order sets increase the efficiency of computerized medication ordering. In addition to the minimally required number of mouse clicks and keystrokes, also the additional (“excess”) number of mouse clicks and keystrokes required by physicians to order medications was lower with predefined order sets than without them. This study furthermore shows that usability problems concerning the information displayed in system messages dialogues, the language and abbreviations used

for labelling of screen items, buttons, and menus, and the feedback given by the system in response to user actions, independently impaired the ordering efficiency.

5.1.1. Effect of predefined order sets on ordering efficiency

It is conceivable that the use of predefined order sets imposes less cognitive and physical demands on users than the use of single orders. This is true not only because order sets minimize the number of actions needed to finalize orders but also streamline the medication ordering process. Predefined order sets guide physicians better through the different steps, reducing the chance of human errors e.g. in calculating the correct medication dosage, which requires extra actions to recover from. In our experiments physicians also came across more usability problems of high severity (major and catastrophic) when they ordered medication without order sets. As exemplified by the excess number of mouse clicks and keystrokes, it then took physicians apparently more effort to solve these problems than when order sets were used. So, order sets also seem to reduce the chance that physicians will come across the same (severe) usability flaws, decreasing the cognitive effort they have to expend to recover from these design flaws.

Our findings are consistent with the findings of Dinning et al. [19], who showed that standardized chemotherapy order sets increased ordering efficiency by significantly reducing the number of changes needed during the order verification process. Our results are also in line with other studies showing that predefined order sets based on protocols are convenient to use [20], can increase the speed of ordering [21] and have the potential to improve provider efficiency by conveniently grouping orders together, making it easier to correctly complete the ordering procedure [22].

Though not a major aim of our study, we also reviewed the resulting medication orders to verify that their quality was not compromised by the increase in efficiency. The results show that the number of incorrect orders related to the ordering with order sets was not higher than the number in ordering without order sets. Besides, if these errors would have reached the patient, the potential harm to the patient would, in the worst cases, have been temporary. Previous studies in different settings have demonstrated that the use of predefined order sets is associated with a reduction in medication ordering errors [23–25].

5.1.2. Effect of usability problems on ordering efficiency

This study showed that three groups of usability problems concerning the information displayed in system messages dialogues; the language and abbreviations used for labeling of screen items, buttons and menus; and the feedback given by the system in response to user actions significantly impaired the efficiency of ordering. Several previous studies have also demonstrated that insufficient system messaging and feedback to support physicians in their natural task flow increases the cognitive effort of physicians to find the required information and prolongs the medication ordering task [10,11,26]. Despite the significant effect of these problems on efficiency many of them could easily have been fixed before system release if existing guidelines and standards for user interface design would have been followed (see for example [27] and [13]).

Generally speaking, each usability problem will require the user to perform additional actions. Nevertheless in our study there seemed to be little influence of usability problems on efficiency other than those related to the aforementioned three categories. In contrast with the results of Horsky et al. [28] concerning the poor display of medication orders, we found that usability problems in the category “Visibility” were associated with a slight decrease in mouse clicks and keystrokes in the multivariable regression analysis. Likewise, usability problems in the category “Others” (e. g. inconsistent use of colors and names, and inability to undo actions) resulted in a reduction in mouse clicks and keystrokes. We believe that these reductions can be explained by the fact that physicians skipped certain non mandatory ordering steps as a result of the invisibility of the system functions or to circumvent other usability problems occurred at certain points in the interaction. For example, one of the physicians did not enter the motivation text for ordering a medication because he could not find the tab activating the data entry field for it. This type of problems, in the end, could result in a lower efficiency of the whole medication ordering and administration process. For example, when physicians do not provide a motivation text for ordering a particular medication, physicians would have to answer phone calls from pharmacists or nurses asking for clarification of the order.

5.2. Strengths and weaknesses of the study

In this study we used the excess number of mouse clicks and keystrokes as a measure of efficiency. We did not use variations in time spent on medication ordering as time measurements may be biased by interruptions such as phone calls and emergencies. Moreover, two individuals might differ in their manual dexterity. For these reasons, the minimum amount of time required for a task to be used in calculation of excess time spent by physicians on that same task cannot be established. While interruptions or differences in manual dexterity could have biased time registrations concerning the duration of physicians’ ordering processes, they do not influence the number of mouse clicks and keystrokes. The approach that we followed in this study for assessing efficiency by using the number of mouse clicks and keystrokes likewise enabled us to analyze physicians’ interactions with the Medicator system. The use of the excess number of mouse clicks and keystrokes for evaluation of ordering efficiency might be a good alternative for time spent on computer-supported tasks especially when the focus is on usability of the application.

To our knowledge this is the first study statistically evaluating the effect of different categories of usability problems on efficiency. The common method used in usability studies for prioritizing usability problems is merely based on their severity rating. Analysis of the effect of different categories of usability problems on efficiency can provide more insight, which can be used to optimally tackle the problem types which significantly affect the ordering process.

We used a counter-balanced design to overcome a potential carryover learning effect of using the system to order the same medications. Although there was no wash-out period between

the physicians’ use of the two methods of ordering, the analysis showed no learning effect from using either method first.

This study however has certain limitations. First, the scenario used in this study is based on one clinical protocol (HOVON 79) used in the hematology/oncology department out of a number of protocols that could be used and implemented through a CPOE system. Although this scenario was designed for ordering chemotherapy, it was designed by an expert in developing clinical protocols, validated by a clinical specialist and tested by two usability experts and covered all of Medicator functionalities for ordering different medications. The use of more scenarios might have shed light on other types of usability problems. Second, the sample size of 10 physicians limits the generalizability of our results. In theory, as the user testing provides a rich source of data, a small sample of participants (approx. 8 participants) suffices to gain a thorough understanding of user’s task behavior [17] and to identify the main usability problems with a computerized system [29]. The inclusion of more physicians however would have allowed statistical analysis of the co-influencing factors such as physicians’ general computer experience on ordering efficiency. The participants in this study included one specialist and nine residents having similar computer experience and the same clinical background. Third, since usability problem at different severity levels (cosmetic, minor, major, and catastrophic) were considered incommensurable, for each severity level the average numbers of usability problem were compared individually between the two ordering methods. This might have resulted in a potential multiple testing problem. Finally, the design of the pre-organized order screens of Medicator may differ from the designs of other CPOE systems. Since Medicator is used in 15 hospitals throughout the Netherlands including large university hospitals, the results of this study can be applicable for all these Medicator applications or those having similar functionalities.

5.3. Meaning of the study and directions for future research

CPOE integrated order sets may, besides increasing ordering efficiency, support physicians during ordering by automatic calculation of certain measures (e.g., medication dosages) based on patient parameters and finally result in better patient outcome by reducing the number of incorrect orders. One of the controversies related to order sets mentioned by Bobb et al. is that most CPOE systems do not mandate the use of predefined order sets but make their utilization voluntary [22]. Based on evidence from earlier studies [30–32] and this study, it would be recommendable to implement mechanisms that make CPOE users aware of the existence of these order sets. Properly constructed computerized order sets can be effective in altering physician ordering practices through standardization [33], thus accelerating and facilitating the ordering process. Progress towards simplifying and speeding up the ordering process may lead to increased acceptance of CPOE [34]. Future research should therefore look into the effect of predefined order sets on physicians’ acceptance of CPOE systems.

Summary points

Already known:

- While the influence of predefined order sets integrated into computerized physician order entry on the quality of patient care has been extensively studied, little is known about the impact of these order sets on ordering efficiency.
- Although computerized physician order entry systems are found to be one of the most effective instruments for reducing medication errors and enhancing patient safety, complex user interfaces of these systems reduce the efficiency of medication ordering.

Known added by this study:

- Predefined order sets can improve the efficiency of computerized medication ordering in terms of the excess number of mouse clicks and keystrokes, without compromising the quality of outcomes.
- The efficiency of computerized ordering can be significantly impaired by specific types of usability problems; mainly concerning vague and incorrect system messages, unfamiliar language for labeling of screen items and non-informative system feedback in response to user actions.

More should likewise be learned about the effect of CPOE usability on physicians' ordering behavior, particularly in relation to the use of CPOE integrated order sets. Usability testing of CPOE systems has not been routine during their development and can be expensive in terms of time and human resources. It is yet an indispensable activity for gaining a better understanding of the impact of CPOE designs on the order entry process, for example in terms of speed of data entry and accuracy of orders, and to assist efforts for improvement of their user interfaces.

6. Conclusion

Independent of the effect of usability problem that physicians may come across, predefined order sets can improve the efficiency of computerized medication ordering in terms of the excess number of mouse clicks and keystrokes, without compromising the quality of outcomes. This study also showed that usability problems concerning vague and incorrect system messages, unfamiliar language for labeling of screen items and non-informative feedback in response to user actions can impair the efficiency of CPOE supported ordering.

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