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Clinicians satisfaction with CPOE ease of use and effect on clinicians' workflow, efficiency and medication safety

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ABSTRACT

Objectives: To study the satisfaction of end-users of a computerized physician order entry (CPOE) system concerning ease of use and the effect on users' workflow, efficiency, and medication safety and to seek users' opinions regarding required improvements of the system. Usability evaluation had shown that this system, which was in use for almost a decade, contained a number of severe usability problems. So another objective of the study was to determine whether there was a direct relation between user satisfaction and the results of a usability evaluation of the system.

Methods: Two survey questionnaires were distributed to CPOE system users (physicians and nurses) working in inpatient departments of a university hospital. Questionnaires included items that were rated using a five point Likert scale. Multiple choice questions with space for free text additions also were used to collect qualitative data concerning the use of the CPOE system and the users' opinion concerning system requirements for improvement. Data were analyzed using descriptive statistics and by the use of Mann–Whitney *U* and Kruskal Wallis tests.

Results: Two hundred seventeen physicians and 587 nurses were eligible to participate in this study (response rate 49% and 56% respectively). Physicians were satisfied with the CPOE ease of use (median 3.8, interquartile range [IQR] 3.3–4), and the effect on workflow (median 3.7, IQR 3.3–4), medication safety (median 3.75, IQR 3–4), and efficiency (median 4, IQR 3–4). Nurses also had a positive attitude towards CPOE ease of use (median 3.6, IQR 3–4), and its effect on workflow (median 3, IQR 3–3.6), medication safety (median 3, IQR 2.5–3.5), and efficiency (median 3.5, IQR 3–4). Users mainly indicated that the system needs: supplementary functionalities (e.g. alerts for allergies), improvement of current functionalities, integration with other hospital information systems and improvement of information presentation (e.g. a clear medication overview). Users did not use some current functionalities because of lack of awareness of the functionalities or having difficulty in using them.

Conclusions: Users of this CPOE system, which was used for almost a decade, were satisfied with the system's ease of use and its effect on efficiency, workflow and medication safety although the system showed many usability problems and lacked some functionalities. In this case study, therefore, there seems no direct relation between the results of the earlier performed usability evaluation and user satisfaction as determined in the current study.

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1. Introduction

A computerized physician order entry (CPOE) system is a clinical application that allows a health care provider to electronically enter orders for patient care. The promise of this system is to support physicians in clinical decision making by alerting them about medication interactions, allergies and wrong dosing, and to improve the quality of patient care by reducing medication errors and adverse drug events [1]. Although it has been shown that CPOE can improve the medication ordering process and enhance patient outcomes [1–5], the rate of CPOE implementation in advanced western countries has been less than 20% [6]. After more than three decades of CPOE introduction, clinician's adoption of these systems has been slow and fitting these applications into routine workflow of clinicians is still a challenge [7,8]. Adoption of information technology is influenced by social and cultural factors [8,9]. Other barriers to the clinicians' adoption of these systems are usability problems including human computer interaction issues causing users' frustration, time delay in ordering, and workflow disruptions that lead to users' dissatisfaction with the system [8–11].

To tackle these barriers, usability evaluation of CPOE aims to provide, from the perspective of human computer interaction, insight into the problems that hinder users during interaction and into their potential effects on the ordering process [12–14]. Studies have shown that the assessment of user feedback concerning the use of information systems provides insight into how to ensure proper system utilization [15,16]. Most of the studies looking at the satisfaction of users concerning CPOE have been conducted at a single institution using a specific type of CPOE system. Therefore more systems in different settings need to be evaluated to be able to generalize the results in the light of the conclusions drawn by others. Moreover, previous studies [17–20] addressed either overall satisfaction or specific aspects of CPOE use (e.g. efficiency or ease of use). These studies also did not specifically evaluate the opinion of users about improvements or additional functionalities needed to enhance the usability and usefulness of the CPOE system.

Usability concerns three different aspects: efficiency, effectiveness and user satisfaction. However, usability problems only are detected as factors diminishing the effectiveness and efficiency of a system. Frøkjær et al. [21] recommend to measure efficiency, effectiveness as well as satisfaction. The relations between efficiency, effectiveness, and satisfaction are not well understood. They found only a weak correlation between measures of the three usability aspects. Generally, the correlations among these usability aspects depend in a complex way on the application domain, the user's experience, and the use context.

We surveyed the satisfaction of users of a working CPOE system concerning ease of use and the effect of CPOE on users' workflow, efficiency, and medication safety. The studies evaluating usability of this system [13,22] identified 57 usability problems of which about 35% were severe. As the use of this system is compulsory, we hypothesized that therefore satisfaction with this system would be low given the high number of usability problems.

We followed the advice of Frøkjær et al. Since we had already studied the efficiency and effectiveness of the CPOE system in this article we studied the satisfaction of the users with the system. We further sought users' opinions regarding what needs to be improved in the CPOE system to increase user satisfaction. This can provide implications/opportunities for systems development, user training, and for effective (re)design of CPOE systems to fully support the ordering process.

2. Methods

2.1. Study setting and the system

This study was conducted at the Academic Medical Center (AMC), a large 1002 bed university hospital in Amsterdam, the Netherlands. We studied a commercially available CPOE system for medication ordering with clinical decision support called Medicator® (iSOFT, Leiden, The Netherlands). The implementation of this system was started in 1997. In 1997 a character-based version of the program, named Medicatie®, became available. Medicator, a windows-based version of the program, was introduced in 2000. Implementation was done by a collaborating management team, project team and help desk. Apart from pharmacy and IT personnel, the head nurse and chief physician of each department were included to streamline the implementation process, to do the planning and to encourage support from physicians and nurses. Implementation of Medicator was completed in 2001 on a large scale across all clinical departments of the AMC except the units where the Patient Data Management Systems (PDMS) was used for ordering medications [23]. During the implementation of the character based version of the program, every new physician was trained individually for approximately one hour and nurses were trained in a group. After full implementation of the Windows version, physicians were trained in groups by an application manager or a pharmacist. Since 2006 e-learning has replaced the group training of physicians. New nurses are taught to work with the system by their colleagues.

The system is used in 30 clinical departments of the AMC. Moreover, 15 other hospitals in the Netherlands also implemented the Medicator system. Medication ordering with this system concerns either single medication ordering or ordering via order sets supported by evidence-based protocols. The system has the capability to recognize drug overdoses, interactions, and double medications and to alert users in those cases. Alerts are presented to physicians in a small window shown on the main screen during the ordering process. Physicians see three buttons accompanying each alert in order to be able to (1) ignore the alert and proceed with the order, (2) stop the previous medication and proceed with ordering the new medication, or (3) cancel the new ordering process. A more detailed description of Medicator was published by Kalmeijer et al. [23].

2.2. Questionnaires

Two separate questionnaires were developed, one for the physicians and one for the nurses, who are the users of

Medicator. These questionnaires were developed based on a preliminary version developed in the Erasmus University and on the previous studies carried out by the authors, including a review of the literature [24], usability evaluations of Medicator [13,22] and field observations and interviews with users of this CPOE system. Ten items from a validated usability questionnaire [25] were included in this survey (6 items in the physicians' and 4 in the nurses' questionnaire).

The first part of the questionnaires asked participants about demographic characteristics. The questionnaires consisted of two types of questions. (1) Questions that could be answered on a five-point Likert scale with the options "strongly disagree" and "strongly agree" at the two extremes to collect data on the users' satisfaction concerning Medicator's ease of use and its effect on the clinicians' workflow, efficiency and medication safety (13 questions for physicians and 12 for nurses). Ease of use included questions concerning user-friendliness of the system, clear presentation of information, and the usability of the system alerts. Workflow concerned questions on timeliness and quality of the ordering process and work support. Efficiency concerned questions on speed of medication prescription and administration and the general efficiency of the ordering process. Medication safety included questions concerning safety aspects of the medications such as right medication in correct dosage and form and the general effect on medication safety. (2) Multiple choice questions with blank space for free text additions to collect qualitative data on issues concerning the use of the CPOE system and on the users' opinion about what needs to be improved in the system (12 questions for physicians and 8 for nurses). Depending on the multiple choice question, participants could select either one or more answers. Not all the questions in both questionnaires were similar, as the physicians and nurses have different responsibilities in the ordering process. For example, physicians were asked about the support Medicator provides during the selection of medication and dosage, and nurses were asked about the clarity of medication order information on printouts of the system. Questions such as those concerning the effect of Medicator on patient safety were the same for physicians and nurses.

Face validity of the questionnaires was assessed by an expert panel consisting of a pharmacist, and five medical informatics professionals of which two had a medical background. They reviewed the items in the questionnaire regarding content accuracy, comprehensiveness, and the scope of the study. Panel members agreed that the content of the questionnaires was consistent with the relevant literature and the study's objectives. Both questionnaires then were tested with three physicians and three nurses and the questionnaires were revised according to their feedback. These questionnaires are available as supplementary material.

2.3. *Participants*

The study population consisted of all physicians and nurses using the Medicator system in inpatient departments of AMC. Eligible participants in this survey were identified by the person responsible for allocating prescriptive or review authority for using the Medicator system. Two hundred seventeen physicians and 587 nurses were identified as being eligible for inclusion in the study.

2.4. *Data collection*

The first author sent e-mail invitations to all potential users through their institutional e-mail accounts. The e-mail contained a brief description of the study, assurance of the anonymity of their responses and a link to the survey website. Reminder e-mails were sent to the non-respondents after around 3 weeks. After submission of the questionnaire the responses to the questions were automatically collected in a database. Since we knew that a number of nurse users do not use their e-mails we delivered paper-based questionnaires and invitations to the head nurses of the clinical departments to be distributed among those nurses. To obtain more responses from the users we encouraged the head nurses to remind all users to fill out the questionnaires. The paper-based questionnaires were accompanied with plain envelopes for returning the questionnaires. In the paper invitation letter the nurses were additionally provided with contact information and the room address of the first author. They were given the choice to either deliver the questionnaire to the head nurse for later collection by the authors or to send it directly to the first author via the mailing system of the hospital. The nurses' responses to the paper-based questionnaire were later entered manually into the database. Since this kind of studies do not require Institutional Review Board (IRB) approval in the Netherlands we did not ask for IRB approval.

2.5. *Data analysis*

Statistical analyses were conducted using SPSS, version 16.0, (SPSS Inc., Chicago, IL, USA). Participants' satisfaction with Medicator's ease of use and its effect on users' workflow, efficiency and medication safety was assessed by averaging the scores given by each participant to questions related to each category. Therefore, the individual means were real numbers instead of integers. Mann–Whitney *U* and Kruskal Wallis tests were used to compare the mean scores of users' satisfaction with each category for different demographic characteristics of physicians and nurses with an alpha level of 0.05. A post hoc Bonferroni correction was carried out with the Kruskal Wallis test to adjust our alpha level. We used descriptive statistics including frequencies and percentages to analyze multiple choice questions and the comments provided by the participants. Content analysis was done on the answers to the question asking physicians and nurses about what needs to be improved in the system. The data were coded and clustered into five categories (improvement of information presentation, adding new functionalities, integration with other information systems, improvement of current functionalities, and others) based on bottom-up analysis of physicians' and nurses statements. The items with a low frequency that could not be categorized were clustered into an "others" category.

3. Results

In total 217 physicians and 587 nurses were eligible to participate in this study. After one round of survey distribution and a reminder, 106 of the physicians' and 327 of nurses' questionnaires were returned (response rate 49% and 56% respectively).

Individual characteristics of the responding physicians and nurses are listed in Table 1. Physicians in the study were relatively young with 71% below 38 years of age. The majority of the responding physicians were residents, working in medical departments and having more than 3 years computer and Medicator experience.

Table 2 presents clinicians' satisfaction with Medicator. The Kruskal Wallis and the Mann–Whitney *U* tests showed that there was no significant difference between the satisfaction of physicians based on their demographic characteristics (gender, age category, function, specialty, computer experience, Medicator experience, and weekly use of system) regarding Medicator's ease of use and its effect on efficiency, workflow and medication safety ($p > 0.05$).

Table 1 – Demographic characteristics of the responding physicians and nurses.

Characteristic	Frequency (%)[a]	
	Physicians ($n = 106$)	Nurses ($n = 327$)
Gender		
Male	54 (51)	53 (16)
Female	52 (49)	274 (84)
Age category		
20–30	23 (23)	86 (27)
31–40	52 (51)	71 (22)
>40	26 (26)	165 (51)
Missing	5	5
Function		
Attending	36 (34)	–
Resident	70 (66)	–
Head nurse	–	5 (2)
Senior nurse	–	53 (16)
Nurse	–	269 (82)
Specialty		
Medical	95 (90)	239 (77)
Surgical	11 (10)	72 (23)
Missing	0	16
Computer experience		
<3 years	7 (7)	37 (12)
>3 years	99 (93)	282 (88)
Missing	0	8
Medicator experience		
<1 year	16 (15)	65 (21)
1–3 years	39 (37)	66 (22)
>3 years	51 (48)	174 (57)
Missing	0	22
Hours a week using the system		
<1	39 (37)	204 (67)
1–2	26 (24)	47 (15)
2–4	19 (18)	34 (11)
>4	22 (21)	22 (7)
Missing	0	20

[a] Missing values were not included.

Table 2 – Clinicians' satisfaction with Medicator.

Satisfaction with Medicator	Physicians median (IQR[a])	Nurses median (IQR[a])
Ease of use	3.8 (3.3–4)	3.6 (3–4)
Effect on workflow	3.7 (3.3–4)	3.3 (3–3.6)
Effect on efficiency	4 (3–4)	3.5 (3–4)
Effect on medication safety	3.75 (3–4)	3 (2.5–3.5)

[a] Interquartile range.

The majority of the responding nurses were female, worked in medical departments and had more than 3 years of computer and Medicator experience (Table 1). Most of the demographic characteristics of the nurses (gender, function, specialty, Medicator experience, and weekly use of system) did not significantly influence their satisfaction with Medicator's ease of use and its effect on workflow, efficiency and medication safety. However there were significant differences in satisfaction among age groups and groups with different computer experience. Nurses in the older age group were more satisfied with Medicator's ease of use and its effect on their workflow and their efficiency than their younger colleagues. Nurses with less computer experience were more positive about the effect of Medicator on their workflow than nurses with more computer experience (Table 3).

Multiple choice questions were asked to collect qualitative information about the use of specific functionalities of the system and the effect of the system on the ordering process. Tables 4 and 5 present the physicians' and nurses' responses to these questions. Since some of the respondents did not answer all questions, the number of respondents to a question may be different than to other questions.

Four of the multiple choice questions were similar in the physicians and nurses questionnaires. The first similar question was about situations concerning the use of Medicator that may cause errors. Fifty four percent of the responding physicians (47 out of 106) and 40% of the responding nurses (130 out of 327) mentioned such a situation. According to the physicians these errors mostly happen during the selection of dosage (18%), administration time (10%) and medication name (7%). According to the nurses the most frequent error-prone situations were the selection of dosage (20%), sending orders for printing (9%) and selection of administration time (8%). The second similar question was whether there were situations that prescription was delegated to the nurses. About six percent (6 out of 95) of the responding physicians and two percent (6 out of 266) of the responding nurses mentioned such a situation (e.g. when the physician trusts the nurse). The third similar question addressed the possibility of medication administration before the physicians order the medications. The rate of positive responses to this question was 92% (92 out of 100) and 89% (279 out of 313) respectively for the responding physicians and the nurses. The fourth similar question concerned coordination of medication ordering activities between nurses and physicians. Verbal communication mentioned by 46% (46 out of 100) of the responding

Table 3 – Breakdown of the satisfaction of nurses about Medicator according to age category and computer experience.

Category	Ease of use median (IQR[a])	Workflow median (IQR)	Efficiency median (IQR)	Medication safety median (IQR)
Age category				
20–40	3.5 (3–3.8)*	3 (2.7–3.7)*	3.5 (3–4)*,[b]	3 (2.5–3.5)
>40	3.75 (3–4)*	3.3 (3–4)*	3.5 (3–4)*,[b]	3 (2.5–4)
Computer experience				
<3 years	3.6 (3.2–4)	3.3 (3–4)*	4 (3–4)	3.5 (3–3.5)
>3 years	3.6 (3–4)	3 (2.8–3.7)*	3.5 (3–4)	3 (2.5–3.5)

[a] Interquartile range.
[b] Although the median (IQR) is similar in both groups the difference is significant because of the difference in the distribution of the data between other percentiles e.g. 10th and 90th percentiles (20–40 years [2–4] and >40 years [3–5]).
* Difference significant at $p < 0.05$.

physicians and 83% (246 out of 295) of the responding nurses as the main means of communication followed by communication via printout labels of Medicator (35% of the physicians and 64% of the nurses).

Seventy-seven percent (75 out of 97) of the responding physicians mentioned that Medicator facilitates coordination of medication activities with at least one of the colleague groups (nurses, pharmacists or other physicians). There were functionalities in Medicator that physicians were not aware of or had difficulties in using them. Seventy-one percent of physicians were not familiar with the functionality with which a distinction can be made between home medications (medications that have been used by patients at home) and hospital medications and 31% of the physicians did not know how to print an overview of the current medication of a patient. Sixty-two percent of the physicians indicated that they found it difficult to make discharge reports using Medicator. The most favored reason for regular use of order sets was convenience of use (indicated by 20% of the responding physicians). Physicians mostly mentioned the low number of order sets (27%) and difficulty to find them (25%) as reasons for not using order sets (see Table 4).

Medicator provides functionalities such as printing out labels (mentioned by 95% of responding nurses) that indicate to the nurses that a new order, or a change or discontinuation of previous orders had occurred. Nurses also mentioned that they use these print out labels to coordinate ordering activities with physicians (64%) and other nurses (66%). However, nurses stated that they still use other means (e.g. verbal communication and phone) to coordinate medication ordering activities. Verbal communication was mostly mentioned (by more than 76% of responding nurses) as a way to coordinate these activities (see Table 5).

Figs. 1 and 2 present the frequency and percentage of physicians' and nurses' responses to items that need to be improved according to them. In the following we provide the percentage of the respondents that mentioned various items. With respect to the category "improvement in information presentation" physicians indicated that the contents of the medication stock of the clinical department and of the pharmacy should be presented on one screen (30%), a patient's medication overview should be presented more clearly on the screen (27%) and on printouts (30%) and the contents of the medication stock should be presented on the main ordering screen (12%). Concerning the category "adding new functionalities", physicians mostly mentioned the possibility to add medications in the discharge report (18%) and addition of alerts for patient allergies (16%). In this category physicians also asked for the possibility of creating individual standard order sets (13%); of ordering via wire-

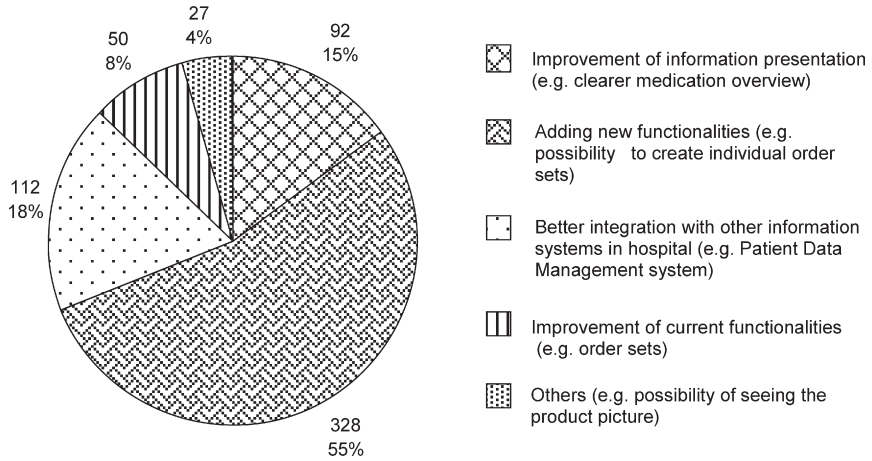

Fig. 1 – Physicians' needs for improvements in Medicator (respondents could select or mention more than one option in each category).

Table 4 – Physicians' awareness of Medicator functionalities and of the effect of the system on the ordering process.

Question	Responses	N	Percentage
Effect on errors			
(1) Is there any situation concerning the use of Medicator that can cause errors? ($n = 106$)*	No	41	38.7
	Yes, selection of dosage	19	17.9
	Yes, selection of time	11	10.4
	Yes, selection of route of administration	6	5.7
	Yes, Medication selection	8	7.5
	Yes, interactions	5	4.7
	Yes, sending orders for printing	3	2.8
	Yes, other Medicator related situations	9	8.5
	I don't know	18	17
	Total	120	
Effect on user activities			
(1) Does Medicator facilitate the coordination of ordering activities with other colleagues? ($n = 97$)*	Yes, with nurses	61	62.9
	Yes, with other physicians	55	56.7
	Yes, with pharmacists	58	59.8
	No, no effect on cooperation	12	12.4
	No, it causes problems with colleagues	10	10.3
	Total	196	
(2) Does Medicator support exchange of medication information during shift changes? ($n = 98$)[a]	Yes, it gives sufficient information about the prescriptions in the previous shifts	38	38.8
	More or less, sometimes I have to take the necessary information from other sources (e.g. the medical record)	47	48
	No, no clear information	7	7.1
	We don't use Medicator for shift changes	6	6.1
	Total	98	
(3) Do you delegate the prescription to a nurse, a nurse specialist or an assistant? ($n = 95$)*	Yes, if I have no direct access to Medicator	2	2.1
	Yes, if I trust that person	5	5.3
	No, never	89	93.7
	Total	96	
(4) Do you ever ask a nurse to give a medication before ordering it in Medicator? ($n = 100$)*	Yes, if I am busy with other patients	31	31
	Yes, if I have no direct access to Medicator	49	49
	Yes, if I trust that nurse	17	17
	Yes, in emergency situations	64	64
	Yes, for harmless medications	9	9
	No, never	8	8
	Total	178	
(5) How do you usually coordinate medication ordering activities with nurses? ($n = 100$)*	Verbally	46	46
	By phone	22	22
	Via nursing record	10	10
	Via medical record	1	1
	Via printout labels of Medicator	35	35
	Via the printout of current Medication Overview	6	6
	Total	120	
Use of system functionalities			
(1) Is Medicator suitable for making discharge reports? ($n = 92$)[a]	Yes	10	10.9
	No, the secretary, who writes the discharge reports, has no access to Medicator.	8	8.7
	No, the information cannot easily be recorded on the discharge report.	57	62
	Not applicable	17	18.5
	Total	92	
(2) Do you use order sets regularly? ($n = 104$)*	Yes, because it is convenient	21	20.2
	Yes, because otherwise the order will not be delivered (e.g. Cytostatics)	4	3.8
	Yes, because it contributes to medication safety	6	5.8
	No, because this option is difficult to find	26	25
	No, because they are few	28	26.9

Table 4 (*Continued*)

Question	Responses	N	Percentage
	No, because I have to adjust them	19	18.3
	No, because it takes a lot of time	5	4.8
	No, because I do not need them	22	21.2
	No, because there is no good order set	3	2.9
	Total	134	
(3) Do you use Medicator to distinguish home from hospital medication[b]? ($n = 100$)[a]	Yes	29	29
	No, I am not familiar with the functionality	71	71
	Total	100	
(4) Do you print a patient's current Medication Overview during the discharge of the patient? ($n = 99$)[a]	Yes, this replaces the list of medications in the discharge report.	10	10.1
	Yes, this is convenient for the patient	24	24.2
	No, I do not know how to make it	31	31.3
	No, it takes a lot of time	9	9.1
	Not applicable	25	25.3
	Total	99	

[a] One answer was allowed.
[b] Home medications: medications that have been used by patients at home.
* More than one answer was allowed.

less networks (10%); and of receiving alerts about incorrect orders (12%), and contraindications (8%); and alerts based on the results of a patient's laboratory test results (9%); and other functionalities (14%). Concerning the category "integration with other information systems in the hospital" physicians demanded integration with the 'Farmaco Therapeutisch Kompas' (a kind of physician's desktop medication information reference in Dutch) (54%), with the Patient Data Management System (18%) and a better integration with the AMC care desktop (a client-platform for viewing all hospital applications) (28%). The mostly requested item regarding the category "improvement of current functionalities" was 'improvement of order sets' (56%). The other items asked for in this category were 'a simpler prescription method for outpatients' (24%) and 'the possibility to turn off medication alerts' (20%).

Concerning the category "improvement in information presentation" the nurses wanted an improvement of the presentation of a patient's medication overview on the screen (43%) and on printouts (57%). Concerning the category "adding new functionalities" nurses asked the possibility of automatically ordering of medications that are not available in the clinical department (from the pharmacy) (16%) and addition of alerts concerning patient allergies (16%). The remaining items suggested by the nurses in this category were 'the possibility to see the list of medications that patient used at home' (16%), 'ordering via wireless networks' (14%), 'the possibility to print the patient's medication overview on discharge reports' (11%), 'adding an electronic kardex' (10%) and other new functionalities (17%). Integration with the Patient Data Management System and improvement of the current functionality to request medications that are not available in the clinical department stock were the only items selected by the nurses concerning the categories "integration with other information systems" and "improvement of current functionalities" respectively.

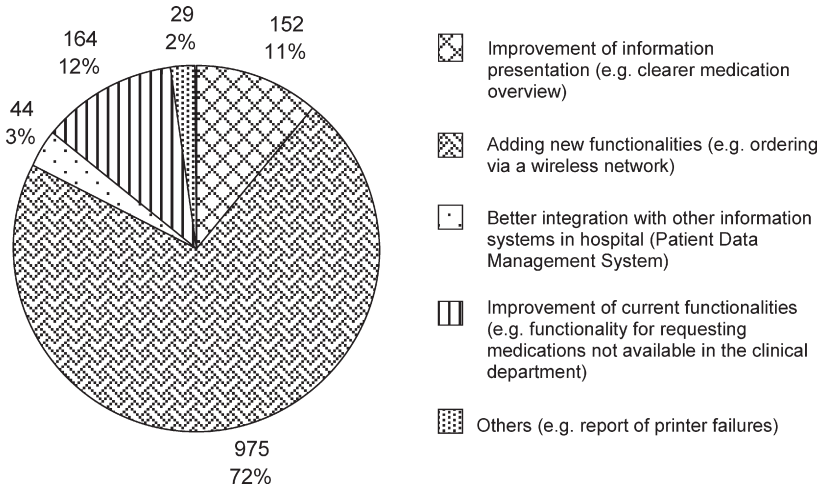

Fig. 2 – Nurses' needs for improvements in Medicator (respondents could select or mention more than one option in each category).

Table 5 – Nurses' awareness of Medicator functionalities and of the effect of the system on the ordering process.

Question[a]	Responses	N	Percentage
Effect on errors			
(1) Is there any situation concerning the use of Medicator that can cause errors? ($n = 327$)	No	64	19.6
	Yes, selection of dosage	65	19.9
	Yes, selection of time	25	7.6
	Yes, selection of the route of administration	7	2.1
	Yes, Medication selection	5	1.5
	Yes, interactions	13	4
	Yes, sending orders for printing	30	9.2
	Yes, other Medicator related situations	22	6.7
	I don't know	133	40.7
	Total	364	
Effect on user activities			
(1) Do you ever enter a patient's medications instead of physicians into Medicator? ($n = 266$)	Yes, when the physician is busy with other patients	2	0.8
	Yes, when the physician has no access to Medicator	1	0.4
	Yes, when the physician trusts me	3	1.1
	Yes, in emergency situations	4	1.5
	No, never	260	97.7
	Total	270	
(2) Do you ever administer a medication before a physician prescribes that medication in Medicator? ($n = 313$)	Yes, When the physician is busy with other patients	105	33.5
	Yes, When the physician has no access to Medicator	87	27.8
	Yes, When the physician trusts me	41	13.1
	Yes, In emergency situations	159	50.8
	Yes, If I get a verbal or written order	107	34.2
	No, Never	34	10.9
	Total	533	
(3) How do you usually become aware of a new order or a change or discontinuation of previous medications? ($n = 295$)	Via printout labels of Medicator	279	94.6
	When the order is removed from Medicator	15	5.1
	Through information by a physician	217	73.6
	By asking the physician	121	41.0
	By a notification in the nursing record	141	47.8
	By a notification in the medical record	21	7.1
	Total	794	
(4) How do you usually coordinate medication ordering activities with physicians? ($n = 295$)	Verbally	246	83.4
	By phone	177	60
	Via printout labels of Medicator	190	64.4
	Via nursing record	135	45.8
	Via medical record	17	5.8
	Not applicable	5	1.7
	Others	5	1.7
	Total	775	
(5) How do you usually coordinate medication ordering activities with other nurses? ($n = 292$)	Verbally	223	76.4
	By phone	15	5.1
	By printout labels of Medicator	194	66.4
	By nursing record	206	70.5
	Not applicable	1	0.3
	Others	10	3.4
	Total	649	

[a] More than one answer was allowed for all questions.

4. Discussion

4.1. *Principal findings*

The results of this study showed that the physicians had a favorable impression of Medicator's ease of use and its effect on their workflow, efficiency and on medication safety. The nurses were relatively positive about Medicator's ease of use and its effect on workflow and efficiency. They were least positive (relatively) about the effect of Medicator on medication safety. Older nurses were more positive about Medicator's ease of use and about its effect on nurses' workflow and efficiency than younger nurses. The nurses with less computer experience were more positive about the effect of Medicator on their workflow than nurses with more experience. Other demographic characteristics appeared to have no impact on the nurses' satisfaction. Our hypothe-

sis that user satisfaction would be low, given the severe usability problems discovered in the CPOE system, could not be accepted. Our results agree however with the results of Frøkjær et al. [21] in the sense that in our study user satisfaction appeared to be relatively independent form the other two factors- efficiency and effectiveness- determining system usability. Both physicians and nurses in this study recommended the addition of new functionalities to Medicator such as ordering via a wireless network and alerting for patient allergies.

4.2. Satisfaction with the CPOE system

4.2.1. Ease of use and effect on efficiency

In the literature there are contrasting opinions about CPOE ease of use and the effect of the CPOE system on efficiency. Consistent with the results of previous studies [17,19,20,26] our results show that users find that the CPOE system is easy to use and improves efficiency. However, another recent study by Rahimi et al. [18] concluded that most physicians and nurses disagreed that a CPOE system is more efficient and easier to use than a paper-based system. The system surveyed by Rahimi et al. [18] did not provide decision support functionalities as was the case with our system and the systems used in the earlier mentioned studies. Of course order entry systems are not all equally usable and their efficiency can be impacted by their ease of use [27]. Users in our study were positive about the CPOE's ease of use although the results of usability evaluations of the same system [13,22] identified a large number of usability problems of various severity levels of which some were mentioned by participants in this study. Participants indicated that the presentation of information on the screen needs to be improved. Consistent with this finding, usability evaluations of this system identified six usability problems related to faulty presentation of medication information of which two were severe [13,22]. For example, a problem was that the system does not present the number of days of the medication duration but only the start and stop dates. Also the usability studies showed that usability problems reduced efficiency and have the potential to cause medication errors. Apparently, CPOE users may perceive a system satisfactory concerning its ease of use and efficiency although it may still suffer from usability problems.

4.2.2. Effect on medication safety

According to a systematic review by van Rosse [5] many studies have shown a significant decrease in medication prescription errors with the use of CPOE. According to Lindenauer et al. [17] the majority of physicians believe that CPOE ordering leads to fewer medication errors. Our results confirm the findings of Lindenauer et al. [17]. This does not, however, mean that CPOE ordering is totally errorless. Around half of the participants in our study mentioned that there are still situations that might cause errors. In accordance with the results of an analysis of a voluntary medication error-reporting database [28], our results show that the most common source of error associated with CPOE is selection of medication dosage. In the usability evaluation of our CPOE we found that due to a suboptimal presentation of the buttons to be used for the calculation of medication dosage physicians may not notice these buttons. Thus physicians would resort to a manual calculation of the dosage, which may lead to medication dosage errors. The next sources of ordering errors reported by physicians and nurses are wrong selections of administration time and route of administration. These problems were also acknowledged as severe problems by the experts involved in the usability evaluations of the system.

4.2.3. Effect on workflow

In contrast with the findings of Lindenauer et al. [17], our findings revealed a high satisfaction of physicians and nurses concerning the effect of Medicator on their workflow. However, our study showed that 10% of the physicians indicated that Medicator caused problems in the coordination of ordering activities with other clinicians. For example, nurses and pharmacists can become irritated due to misunderstanding of a physician's remarks, or physicians need to reenter orders when patients are moved to another department. This type of problems was also identified by the usability evaluation [22], for example, users could not enter their motivation of ordering a specific medication in the required field. This led to time consuming calls of the pharmacists and nurses to the physician to clarify the order. However, more than 57% of the physicians emphasized that Medicator facilitates the coordination of activities with nurses, pharmacists and other physicians. The results showed that although the ordering of a new medication or changes in or discontinuation of previous medications is communicated through the CPOE system to the nurses, this does not yet suffice in meeting communication needs of users in all situations. Dykstra [29] showed that CPOE introduction changes communication patterns between physicians and nurses, and may create an illusion of communication, meaning that clinicians think that just because the information is in the computer, the right person will see it and act on it appropriately. Nurses in particular should stay aware of new medications ordered by physicians through use of CPOE. Our physicians yet indicated that they sometimes use other means of communication (e.g. phone) to contact nurses about initiating or changing an order, or to make sure that the nurses received the order correctly; and nurses contact physicians to ask for explanation about a new order or to request a reprint of the order, which failed to be printed the first time.

It was surprising that older nurses were more positive about the ease of use of Medicator, its effect on workflow and their efficiency than younger nurses and also less computer experienced nurses were more positive about the effect of Medicator on their workflow. In general, older people tend to have less knowledge of and experience with technology and may experience more difficulty in using technology than younger people [30,31]. Computer-based work takes longer for older people and they make more errors [32–34]. Since in the AMC the Medicator system has been in use for around 10 years now, older nurses were as familiar with its functionalities and use as the younger nurses. Practice by older people can result in performance improvements in the use of computer technology [35,36] and has a positive effect on older people's attitudes towards technology [37]. Moreover, since interactive and multi-functional electronic devices are increasingly used by younger people and becoming a part of

their daily life, younger nurses may have higher expectations of the ease of use of computer technology (Medicator in this study) and the effect of this technology on their efficiency and workflow. Likewise more computer experienced nurses may have a higher expectation of the effect of the system on their workflow.

4.3. *Insights for improvement of CPOE*

While the respondents were positive about Medicator's ease of use and its effect on users' workflow, efficiency, and medication safety, their responses to other items made it clear that there is a difference between what physicians and nurses would like and what the current ordering system provides. For instance, only 39% of the physicians indicated that the system provides sufficient information about the prescriptions to be shared with colleagues during shift changes. The respondents' need for other means of communication to exchange the information regarding the orders is another example.

The respondents made several suggestions that are worth noting. First, improvement of departmental order sets and the provision of individual standard order sets were requested by a large number of the physicians. Physicians mentioned a low use of current order sets because these order sets are difficult to find, need adjustments and are few in number. In the study by Rosenbloom [19] the tools most favored by the users were individual order sets. Another study showed that around 70% of the users stated that order sets were important for an efficient use of the system [17]. Our previous usability study showed that ordering with order sets is more efficient than ordering single medications [22]. A concern in using information systems is the amount of effort needed to carry out a task. As we already showed in a previous study, order sets required less effort from the users to complete an ordering task. Therefore, attention should be paid to the implementation of order sets to increase physicians' efficiency. Second, respondents indicated a need for additional alerts concerning allergies, contraindications, incorrect orders and the results of a patient's laboratory tests besides the currently available alerts (drug–drug interaction, overdose and duplicate medication). This was in accordance with the results of the usability evaluation, e.g. lack of an alert when the dosage was not in accordance with a patient's age, was mentioned by the participants in the usability testing [22]. Adding the functionalities most relevant to the different user groups will lead to a higher user satisfaction. Likewise, the quality of medication prescribing may be improved by adding such functionalities. However, it will require substantial effort to develop and maintain functionalities that are useful to the users. Also, the majority of the already available alerts are overridden by users and therefore do not effect the final prescribing decision [38]. Therefore, caution should be taken when deciding about additional CPOE functionalities. In the case of alerts, for example, the developers should study measures that will prevent alert fatigue. The results of our systematic review [24] showed that consideration of factors like timeliness, consistency of location on screen, briefness, specificity and informativeness in the provision of evidence could contribute to the acceptance of alerts. Third, both physicians and nurses requested ordering via a wireless network. It was shown by Beuscart et al. [39] that when using CPOE, physicians and nurses miss the synchronous dialogue during rounds that plays an essential part in the coordination of actions throughout the medication ordering and administration process. Using a wireless network facilitates communication between nurses and physicians during rounds and results in better coordination of ordering activities.

The results of this study also showed that not all of the respondents were aware of all available system functionalities and some had difficulties in locating system functionalities. This confirms our usability results that poor visibility of screen buttons hinders users from noticing and using system functionalities [13,22]. Clear presentation of information (e.g. of a patient's medication overview) and presentation of related information (e.g. the contents of the department's and the central pharmacy's stock) on the same screen would increase the usability of the system. Participants in the usability testing [22] were confused when the system warned that an ordered medication was not available in the stock of the clinical department. Users had no idea that there was a pharmacy stock option somewhere on the previous screen that they should select to finalize the order.

Satisfaction of the users with this system in spite of the presence of usability problems that were acknowledged by the users in the survey can be explained as follows. Lindgaard [40] indicated that people may be more satisfied with a beautiful product that performs sub-optimally than with a more usable but less appealing product. Perhaps a system that has been in use for ten years and has had several updates is considered as such a beautiful product by its users who on the other end also suggest points for improvement of the system. Usability studies [22,41] show that physicians use workarounds to perform ordering tasks when they experience a usability problem. They may feel convenient to work with the system as they get accustomed to workarounds. Moreover, it has been previously shown that initial training and frequency of use result in familiarity with the system and can increase satisfaction with the system [42]. This may be the case for this system that is used for around 10 years. Socio-technical factors also can contribute to the satisfaction, for example because of the organizational culture people may have a tendency to appreciate the systems used in the organization.

5. Strengths and weaknesses

Other studies [17–20,26,27,42] questioned their respondents about their satisfaction with CPOE systems and compared satisfaction with different systems or among different types of users. The satisfaction measure in this type of studies fails to point to particular user interface issues that could help the designer understand how to improve the design [40]. In the present study, in addition to the evaluation of the users' satisfaction concerning different aspects of Medicator (ease of use and effect on efficiency, workflow, and medication safety), we collected data on the users' satisfaction of the current functionalities of the system and about the functionalities that users felt needed to be improved or implemented in the

system. Moreover, we linked the results of this study to the findings of usability studies of the same system [13,22] to show that the users realized that the system had usability problems and discussed the potential reasons why the users were nonetheless satisfied with the system.

Unlike other studies, we did not compare the satisfaction of the physicians and nurses. Physicians and nurses constitute two very different types of users that interact with the system differently. As a consequence, their satisfaction about different aspects of Medicator may depend on the way they use the system.

This study has certain limitations. First, we did not formally validate the questionnaires. However, the questionnaires were designed based on results from previous studies carried out by the authors concerning CPOE designs (impacting usability, workflow and medication orders) [24] and usability of a CPOE system [13,22], and based on field observations and interviews with Medicator users. Also items were included from a validated questionnaire by Lewis et al. [25]. The face validity of the questionnaires was determined in consensus meetings of six professionals having different backgrounds and finally a sample of six users answered the questionnaires and commented on their content. Therefore, we believe that these questionnaires were adequate to evaluate the satisfaction of users concerning Medicator and to determine the areas that needed improvement. Second, similar to other surveys conducted in comparable settings this study investigated one CPOE system at one academic medical center. It is possible that the users' satisfaction with other systems at other locations may differ from those reported here. However, this study adds to the body of knowledge about users' satisfaction and CPOE requirements. Third, the relatively low response rates (49% for physicians and 56% for nurses) in this study might have introduced selection bias. We have no data from the non-respondents to assess the direction or amount of the potential selection bias.

6. Conclusions

This study revealed that in general users of the Medicator system were satisfied with the various aspects of this application (ease of use, effect on efficiency, workflow and medication safety). This study provides another example, in addition to the work of Frøkjær et al. [21], that high user satisfaction does not need to be related to a high efficiency and effectiveness of the system. Although some CPOE functionalities (e.g. order sets) are provided to facilitate and accelerate the ordering process, the users mentioned lack of awareness of or difficulties with using current system functionalities, which can prohibit the use of these functionalities. To overcome these problems the users' awareness concerning current functionality of the system should be increased by providing clues and icons, a better presentation and alignment of items on the screen; and by providing extensive training and educational materials. Based on the results of this study we conclude that although satisfaction is a predictor of system acceptance and use, a system that has a high user satisfaction might still contain usability problems and need improvement of its functionalities.

Summary points

Already known:

- Satisfaction with CPOE varies widely among different groups of users and different systems.
- Satisfaction is a predictor of CPOE adoption and use.
- The literature is not univocal about the correlation between the three usability aspects efficiency and effectiveness and user satisfaction.

Knowledge added by this study:

- Users of the studied CPOE system are positive about system's ease of use and its effect on efficiency, workflow and medication safety although they requested improvements of system functionalities.
- This study provides additional evidence of the fact that high user satisfaction with a system does not need to be related to a high efficiency and effectiveness of the system as perceived from the number of usability problems that users experience.
- Although some CPOE functionalities (e.g. order sets) are provided that facilitate and accelerate the ordering process, usability problems may negatively effect the use of these functionalities.

Author contributions

R. Khajouei, P.C. Wierenga and M.W.M. Jaspers contributed to the conception and design of the study. Data collection was done by R. Khajouei and P.C. Wierenga. R. Khajouei performed the analysis and interpretation of data, and prepared the first draft of the manuscript. Arie Hasman critically revised the content of the manuscript. All authors participated actively in the editing of the manuscript and approved its final version.

Conflict of interest

The authors have no conflicts of interest to declare.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.ijmedinf.2011.02.009.

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