Nurses’ Evaluations of a Novel Design for an Electronic Medication Administration Record

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An electronic medication administration record (eMAR) is at the intersection of medicine, pharmacy, allied professions, and nursing within an electronic health record or EHR. At its most basic level, an eMAR displays ordered medications for inpatients in acute care settings; however, this notion belies the complexity, both functionally and technically, for healthcare practitioners. The premise of such an application is that physicians enter orders electronically using an orders module; these orders are then displayed on the eMAR according to the scheduled medication times. Pharmacists use the orders module or eMAR to review, verify or modify medication orders, and then dispense medications according to the eMAR to the correct patient care unit at the correct times. Nurses use the eMAR, their sole reference source for medication management. The eMAR assists nurses with the “five Rs” (Right patient, Right drug, Right dose, Right route, Right time). After nurses administer medications, they use the eMAR to document medications given or provide reasons for medications not given.

Functionally, the eMAR must display a large variety of and routes for medications, from tablets, intravenous, intramuscular, subcutaneous injections to total parenteral nutrition (TPN) and sublingual medications. In addition, medication orders may be accompanied by extensive instructions, or they may need to be linked to other conditions, such as verifying a laboratory order before a medication can be administered (for example, linkages between the serum potassium level before digoxin is given). Orders are also linked to documentation in some cases; nurses need to document a patient’s pulse before digoxin is given. Other complexities include the fact that some medications are scheduled, and others are as needed (or PRN) within certain time...
The eMAR needs to satisfy disparate tasks for each of the varied disciplines. For medicine, the eMAR is used to track and trend medications due and those administered. For example, a physician may use the eMAR to monitor specific medications (eg, the cumulative amount of regular insulin given to a diabetic during a 24-hour period). Physicians might also need to refer quickly to the eMAR to see when the next dose of a specific medication is due for a particular patient. Physicians often use the eMAR as a quick reference for the complete listing of current medications ordered for a patient. Allied disciplines primarily use the eMAR as a reference for specific tasks, such as determining whether a pain medication was recently administered before physical therapy is attempted.

Yet with its various users, the eMAR’s heart and soul is centered on nursing. Nurses use the eMAR to organize their medications for administration to a number of patients for a certain period of time, such as an entire shift, or for access to single medication, such as a pain medication provided for a particular patient on demand. The eMAR is also used as the resource document during change-of-shift report to communicate when crucial medications were last given and which might need to be given imminently by the oncoming shift. As the main source for medications, an eMAR needs to be readily accessible, near the actual medications themselves, and yet also near the patient so that nurses can use the application as a ready reference and to document the medications administered. For example, for PRN medications, nurses must quickly be able to identify when the last pain medication was given and when the next one can be safely given.

An eMAR should be the integration point for orders; stocked medications in the pharmacy; interdisciplinary documentation; correlated laboratory values; drug-drug and drug-allergy interactions; medication-dispensing devices; billing; and bar-coding technology. Without this technical integration, work is fragmented, and the potential advantages gained from having an eMAR are lost.

Clearly, the design of the eMAR is complex and crucial to patient safety. It needs to be designed to allow for efficient and effective work organization, especially for nurses, because medication delivery is one of the most important aspects of patient care. The eMAR should also serve to facilitate communication within and among several disciplines. Even with the complexity and multifaceted use of eMAR, design and evaluation work should begin with nurses’ requirements because they are the primary eMAR users.

Despite the critical role of an eMAR in patient healthcare delivery, eMARs have received little attention by developers and informaticists. In fact, the human factors and healthcare literature databases are virtually silent about recommendations for the design and evaluation of eMARs.

Several EHR vendors have developed initial eMARs, yet no systematic evaluations of these systems are available for review. An informal examination of several vendors’ eMARs yielded several usability issues:

- One large vendor’s design lacks a word-wrapping capability in the order window, resulting in a display of only a partial order—a potential patient safety issue.
- Some eMARs lack the complete set of medication orders (missing TPN, chemotherapy, or even basic IV orders), resulting in the lack of a consolidated display for the full suite of medications ordered for a patient.
- Several vendors have no search or filtering capabilities, so nurses must sort through orders on all patients on their units to find the appropriate medications due for a specific time for their patient(s).
- Some eMARs have no obvious indicators for medications or times outside the field of view, potentially resulting in missed medications.
- Other eMARs lack indicators for differentiating among types of tasks, such as medications due, those given, and PRN medications versus scheduled medications.

Kohn et al have suggested that the systematic assessment of crucial tools such as an eMAR is important for three reasons: the general requirement for healthcare’s concern for patient safety; the recent attention about EHR implementation and interoperability emphasize the need to have more standardized designs for common elements such as the eMAR; and the advantages of adequate interface testing and usability testing are well known outside healthcare, but these techniques have not been adopted widely in healthcare.

Better designed systems can allow for correct data entry, display, interpretation, and better contribute to sound clinical decision making and error prevention. Other impacts include decreases in time to complete tasks, user disruptions, training time, software rewrites, and burden on support staff. Within healthcare, reported that usability can streamline data entry and allow for as much as a 10-fold decrease in the average number of reported user problems after installation. Usability techniques not only allow for naming user problems with systems, but they can specifically address why users are having those problems. Then, recommendations can be made to developers for redesign. This is especially important early in application development.
Purpose of the Study

This study was designed to address some of the issues outlined. As one of the first usability assessments of an eMAR, this study is an exploration into the development and evaluation of a safe and effective eMAR for nurses as primary users of an eMAR. The purposes of the study were to:

1. Determine critical nursing medication activities to be supported by computerized medication orders management for safe and effective on-line performance.
2. Evaluate a new prototype design for an eMAR to determine nurses’ on-line interactions during on-line medication management tasks.

Conceptual Framework for the Study

The theoretical basis for this study consisted of two levels. First, the macroscopic level of the conceptual framework for the study is displayed in Figure 1. It is an overall look at interdisciplinary human-computer interaction. In this framework, human-computer interaction is conceptualized as a task-based information exchange among providers, patients, and computers. The interaction is embedded in a context and moves along an informatics trajectory over time. Providers and patients, according to their characteristics, drive the interaction process and exhibit task performance behaviors. Computers complete actions displayed on computer screens in response to task behaviors and related to specific computer (software and hardware) characteristics. This study focuses on the nurse-computer interaction component of the framework as critical for development of an efficient and effective eMAR.

The second level of the study’s theoretical basis identifies more detailed study variables related to the specific nurse characteristics, behaviors, and computer actions in the conceptual framework. In this study, computer actions are depicted by the interface displays in the new eMAR. Nurses’ characteristics are described (demographics and computer experience), and nurse behaviors concentrate on the nurses’ interactions with the eMAR (accuracy) and their perceptions of the efficiency and effectiveness of the eMAR interface design (user interaction satisfaction and assessments of the design).

Critical Medication Management Activities

The study was approved by the Institutional Review Board in the different organizations. In the first phase of the study, a purposive sample of 12 Army, Navy, and Air Force clinical staff nurses from an acute care setting, university setting, and a primary care clinic was used to discover critical medication management activities. Semistructured questions about medication management activities guided participants’ responses, which were videotaped at a large military medical center in the western US. In addition, several nurses were asked to “talk aloud” during actual medication management activities. Functional decomposition diagrams (process flows) were crafted from participants’ information. The diagrams were then validated by participants. One aspect of the process is depicted in Figure 2; the others are available by request.

![Figure 1](image-url)
**eMAR Design and Evaluation**

The task activity information from the flow diagrams was used to create a prototype eMAR (Figure 3). The eMAR was populated using the current pharmaceutical formulary for the hospital and typical patient records to depict realistic patient care scenarios. Three graduate nurses pilot tested the new eMAR to: determine the length of time the study would take, discover any errors in the application, and correct any clinically irrelevant information.

**METHODS**

In the second and evaluation phase of the study, 20 Navy clinical nurses (four male, 16 female) volunteered for the eMAR evaluation study in response to posters.
and e-mail at a large military medical center in the western US. The participants' nursing experience had a range of 28 years (M = 7.83). Systems currently used by the participants included Composite Health Care System I (used by the US Military) (6); Pyxis (Pyxis Products, San Diego, CA) (8); CliniComp (CliniComp International, San Diego, CA) (13); MAR (1); SF600 (used by the federal government) (1); and Pickpoint (Pickpoint Corp., Pleasanton, CA) (1). The mean age for the sample was 34 years. Participants were tested in small groups in a quiet computer training room adjacent to the medical center. Participants took 45 to 75 minutes to complete all assigned tasks required during the evaluation.

After introductions, participants signed consent forms and filled out demographic questionnaires. The Staggers Nursing Computer Experience Questionnaire (SNCEQ) was used to identify participants’ computer experience.

SNCEQ. The SNCEQ is composed of eight subscales measuring nurses’ self-reported general and hospital

FIGURE 3. Sample eMAR screens.
information system (HIS) computer knowledge, general and HIS computer use, and knowledge of and participation in informatics role activities. The instrument takes 5 to 8 minutes to complete. Content and construct validity and test-retest reliability of the instrument were previously assessed and reported.6 Internal consistency using Cronbach alpha ranged from .86 to .95 for the subscales. The psychometrics for the instrument indicate adequate validity and reliability.

The software program Captivate (Adobe Systems, Inc., San Jose, CA) was used to construct a standardized tutorial for the eMAR. This program allowed instructions to be superimposed over the program screens, guiding the nurse-users through the typical tasks of selecting patients, creating a tailored patient roster, adding, modifying and discontinuing medications, looking for medication interactions, and finding special instructions for particular medications, determining the “big picture” view of medications due, given, and overdue.

The new eMAR is a Web-based application that was accessed via the Internet during the study. The scenario study tasks were given to participants to complete as they interacted with the new eMAR. Participants seated next to each other were given different sets of the same task orders. The task order was different to avoid a learning effect and to avoid participants consulting with each other for answers. Participants were asked to perform two each of typical tasks, such as adding, modifying, and discontinuing medications. In addition, the tasks were as realistic as possible, for example:

- As you come on to your shift at 1500, are all your patients’ medications up to date?
- How many of your patients have medications due at 1700 today?
- When is the next dose of Lopressor due for John Smith?
- Modify Zofran 8 mg PO (orally) from every 8 hours PRN to every 6 hours PRN
- What medications have been discontinued for Mary Smith?

All user keystrokes were captured during the completion of each of the tasks for time and accuracy calculations. After the last task was performed, participants completed the Questionnaire for User Interaction Satisfaction (QUIS) and informal user satisfaction questions.

QUIS. User interaction satisfaction was measured using the QUIS (version 7.0), which was developed at the University of Maryland Human-Computer Interaction Laboratory.7 Bipolar adjectives and nine-point Likert scales are used for topics of user interactions (screen factors, terminology and system feedback, learning factors, system capabilities). The instrument was assessed for internal consistency and construct validity.8

Table 1
The Sample’s Scores for Previous Computer Experience

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
<th>Range</th>
<th>Total Possible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer application use</td>
<td>35.65</td>
<td>12.97</td>
<td>11</td>
<td>72</td>
<td>61</td>
<td>80</td>
</tr>
<tr>
<td>HIS use</td>
<td>32.70</td>
<td>7.96</td>
<td>15</td>
<td>44</td>
<td>29</td>
<td>48</td>
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<tr>
<td>Computer application knowledge</td>
<td>34.16</td>
<td>13.26</td>
<td>11</td>
<td>71</td>
<td>60</td>
<td>80</td>
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<tr>
<td>HIS knowledge</td>
<td>31.89</td>
<td>7.77</td>
<td>20</td>
<td>44</td>
<td>24</td>
<td>48</td>
</tr>
<tr>
<td>Subtotal knowledge and use</td>
<td>134.4</td>
<td>10.49</td>
<td></td>
<td></td>
<td></td>
<td>256</td>
</tr>
<tr>
<td>Role activity</td>
<td>2.80</td>
<td>5.33</td>
<td>0</td>
<td>22</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>Role activity knowledge</td>
<td>3.17</td>
<td>5.51</td>
<td>0</td>
<td>22</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>Formal computer knowledge</td>
<td>3.15</td>
<td>3.19</td>
<td>0</td>
<td>12</td>
<td>12</td>
<td>16</td>
</tr>
<tr>
<td>Level of computer experience rating</td>
<td>3.26</td>
<td>1.33</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Total score</td>
<td>140.37</td>
<td>8.00</td>
<td></td>
<td></td>
<td></td>
<td>320</td>
</tr>
</tbody>
</table>

Table 2
User Interaction Satisfaction Scores

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Sample Size</th>
<th>Missing</th>
<th>Summed Mean</th>
<th>Item Mean</th>
<th>Percent SD</th>
<th>Min</th>
<th>Max</th>
<th>Range</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall user reactions</td>
<td>18</td>
<td>0</td>
<td>43.3</td>
<td>7.2</td>
<td>80.2</td>
<td>8.0</td>
<td>29</td>
<td>54</td>
<td>54</td>
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<tr>
<td>Terminology and system information</td>
<td>19</td>
<td>1</td>
<td>119.6</td>
<td>7.5</td>
<td>83.3</td>
<td>18.7</td>
<td>72</td>
<td>144</td>
<td>144</td>
</tr>
<tr>
<td>Learning</td>
<td>19</td>
<td>0</td>
<td>97.8</td>
<td>7.5</td>
<td>83.3</td>
<td>12.0</td>
<td>67</td>
<td>115</td>
<td>117</td>
</tr>
<tr>
<td>On-line tutorials</td>
<td>19</td>
<td>3</td>
<td>101.0</td>
<td>7.8</td>
<td>86.7</td>
<td>14.16</td>
<td>62</td>
<td>117</td>
<td>117</td>
</tr>
<tr>
<td>Multimedia</td>
<td>17</td>
<td>6</td>
<td>31.6</td>
<td>7.9</td>
<td>87.8</td>
<td>5.3</td>
<td>16</td>
<td>36</td>
<td>36</td>
</tr>
</tbody>
</table>

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The internal consistency scores for the scales ranged from .88 to .96.

**eMAR EVALUATION RESULTS**

**Computer Experience**

Table 1 summarizes the mean scores for computer experience for this sample. The mean SNCEQ scores were slightly less than half of the available scores for computer application use and knowledge. In contrast, the mean scores were approximately two thirds of the total available points for HIS knowledge and use. Thus, the sample's knowledge and use of clinical information systems exceeded their use and knowledge about general (personal) computers. The sample's role activity and knowledge is low (slightly more than three of the 24 possible.)

**Interaction Satisfaction**

QUIS scales included in this study were: terminology and system information, learning factors, on-line tutorials, and four items from the multimedia subscale. As noted in Table 2, the mean for the overall user reaction subscale was 80.2%. The other mean subscale scores ranged from a low of 80.2% (overall) to 87.8% (multimedia). The overall reaction score is the lowest rating of the subscales. In addition, for individual item scores on the entire instrument, the lowest scores were for time to learn to use the new system (6.89) and speed of the presentation (5.78). The highest individual item scores were about the helpfulness of the tutorial (8.05), learning to operate the tutorial (8.16), time given to perform tasks (8.32), completing tasks after using only the tutorial (8.11), and the overall rating of the application as easy (8.22).

**Task Accuracy**

Overall, 90% of all tasks were completed correctly by nurses; however, results for different task types varied. Selecting the correct patient care unit, frequency of medications, correct patients for a tailored patient list, determining the correct route for medications, and performing a drug-drug interaction check were not problematic. Half the participants were also able to successfully cancel a medication when they determined that errors in data entry occurred. However, participants had difficulty determining whether patients were up to date on their medications (5% accuracy) and counting the routes and numbers of medications (24% accuracy). While overdue medications were obvious (in red), participants neglected to scroll backward in time to examine medications and routes out of the field of view.

**Informal User Satisfaction Comments**

Participants’ comments were very positive overall. In particular, the icons for medication routes and color coding for due, past-due, administered, and future medications were rated very positively (“Loved it! “Overall I loved the system and can’t wait to start using it!”). Being able to select only pertinent patients, as opposed to seeing the whole list of patients on a unit, was deemed very helpful, and this feature potentially decreased errors. Having a feature to document verified medications (two nurses must check accuracy) was deemed very positive.

On the other hand, nurses working in faster-paced areas, such as labor and delivery, thought the eMAR was too complex for their standardized medications and quick patient turnaround (“too many hoops to go through”). Other comments centered upon expanding the field of view to 12 or even 24 hours, making a current patient’s name even more obvious, and accommodating a range of medication doses. Last, the tutorial, which was either self-paced or autopaced depending upon user preference, provided good instruction but was too slow for three of 20 users, who wrote informal comments about the slowness of the tutorial.

**DISCUSSION**

**Computer Experience**

Nurses’ scores for HIS use and knowledge were higher than for general computer knowledge and use. Nurses’ computer application experience concentrated in word processing, documentation of patient care activities (charting medications, nursing assessments), use of the Internet, and e-mail. This current sample shows a higher level of overall computer experience than previous work,9 for which the mean score for use and knowledge was 105. Perhaps this indicates a gradual maturing of nurses’ computer experience in the work setting. An alternate explanation is that this site has had clinical computing in place for a decade. Although the nurses rotate to other sites about every 3 years because of military assignments, there is always an available cadre of computer savvy nurses who are well versed on the clinical computing applications in place, training methods are mature, and the applications themselves are also mature and deemed a normal part of patient care activities.
The current SNCEQ computer use and knowledge scale is targeted to required work tasks, those that are almost survival requirements at work. Broad use of computers and broad computer knowledge, at least in this sample, has not yet occurred, but it is improving with time. Because this site has had its clinical information systems in place for more than a decade, the experience level in this sample may not be generalized to all nurse samples. Informatics role activity knowledge and use is low, as would be expected in a sample of clinical staff nurses. An encouraging finding is that only three nurses said they did not use computers much, one because of little interest in computers and two others because they feared losing data. This is an evolution toward increasing computer use compared with the responses of nurses in earlier studies.

**eMAR User Interaction Satisfaction**

The results of this analysis demonstrate positive user satisfaction with the new eMAR. Nurses rated the ease of use very positively, especially the ease to learn the application. The actual performance of the interface was likely confused with the tutorial because a few of the participants mentioned slowness as an issue. The tutorial was set initially to be autopaced; however, as part of the instructions, self-pacing was an option. Apparently three of 20 users chose not to exercise that option or perhaps forgot that the option was available. The application itself was very fast, with no network delays and screen changes at the speed of the Pentium processor.

The participants’ text comments were positive overall, even enthusiastic. Some participants had specific suggestions about improvements. The graphical depiction of medications was well received by the nurses. Perhaps this is because it provided variety to the massive amount of text elsewhere in an EHR.

The overall rating for the application was very good, but there is room for improvement. Mean scores were above 7.0, with a few mean scores above 8.0. As specified in the results section, the higher scores were clustered on learning the application and its overall rating as easy to use. In contrast, the terminology, system feedback, and screen subscale scores were in the 7s, and the overall subscale scores were in the low to mid 7s on a scale of 1 to 9. The mean scores in this study are slightly less than the Graphical User Interface in an earlier study; however, the earlier study was a comparison study of a character-based application and a Graphical User Interface, a great contrast in user interfaces. The scores and comments point to a need for more design work for fast-paced areas and consistent feedback to the user.

**User Interaction Accuracy**

Of particular concern was the accuracy issue about whether medications were up to date for patients and other tasks that required scrolling outside the current field of view. Although these were first-time users of the interface, additional design work is needed to remind nurses, especially those new to the application, about medications outside the field of view. Expanding the view to 8 or 12 hours can help, but with any computer display, especially Web-based ones, there is limited real estate. Thus, exceptionally clear indicators of “MORE” on the sides of the viewable area must be available. The appearance of a traditional, gray scroll bar is far too subtle. Increasing the real estate by using progressive disclosure for less common tasks, such as modifying medications, can expand the viewable field.

**Learning the Application**

The number of positive scores and comments in participants’ remarks indicate the application was easy to learn. The negative comments surrounded the autopacing of the tutorial. In fact, users could select an option for self-pacing but did not. In the future, an on-line tutorial should be set up to be individually paced as the standard option.

**Conclusions and Implications**

This study determined critical on-line medication management tasks for acute care nurses. Subsequently, the study developed and evaluated a new eMAR prototype design. The usability assessment for this new eMAR was positive, according to ratings from the QUIS, which ranged from 80.2% to 87.8%. Specific design recommendations were outlined for future eMARs.

The implications from this study are several. First, the design principles used to create the new eMAR may be employed by application designers anywhere. The eMAR development in EHRs is not mature yet, so this study is timely and may serve as a benchmark for future application development. The mixture of graphics and text likely helps nurses discriminate among items in a sea of text in EHRs.

Second, the complexity of an eMAR has been underestimated by most designers in the past. An eMAR is used by many disciplines—nurses, pharmacists, physicians, respiratory care, and others. Therefore, the eMAR is a convergence of orders, pharmacy distribution, and dispensing devices. More importantly, the eMAR is a core element of patient safety, especially for nurses’ medication tasks. The design presented here acknowledges the basics of complexity for nurses’ tasks.
inherent in an eMAR and gives design methods to begin to address that complexity.

This study addressed nurses’ task completion with an eMAR as the first step in entangling the complexity of interdisciplinary designs. More importantly, nurses are the major users of an eMAR. In future research, the eMAR design should be evaluated with other major stakeholders for efficiency and effectiveness of task completion.

Third, the importance of a safe design in this study, where it worked and where it did not, was made clearer by this evaluation. EMAR design has not been well documented in the literature, nor has it received adequate attention by system developers.

Fourth, the on-line tutorial provided an excellent learning tool for nurses. Although the pace was fine for most when it was autopaced, researchers may want to have users in the future pace the program themselves.

The military sample, the fact that this site has had a decade of clinical computing, and the convenience sampling method may limit the generalizability of the study. However, the tasks are typical of those performed by nurses everywhere. Additionally, the quiet setting allowed for study control, but nurses’ usual work is filled with task interruptions. In this sense, the context may not be representative of medication management activities in a more naturalistic, interrupted, and busy setting.

Future studies should expand beginning eMAR capabilities into the design of special cases, such as tapering medication doses, multiple methods for medication routes and complex medications (chemotherapy protocols or TPN), and fast-paced environments. Future researchers may wish to explore why the overall QUIS subscale achieved a lower rating than its other subscales. Evaluating the use of an eMAR in a more naturalistic setting would also be useful. Last, a next step in evaluations should include a multidisciplinary sample. In summary, this study starts a design dialogue and provides evidence for how to increase patient safety through effective eMAR design.

Acknowledgments

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