# A Comparative *In-Situ* Study of Two Medication Reconciliation Interfaces in Pre-Operative Nurse Assessments

**Benjamin Duncan, BS[1]; Andrew Solomon, BS[1]; Bradley Doebbeling, MD, MSc[1,2,3]; Stephanie K. Furniss, PhD[1,3] Adela Grando, PhD[1,3]; Karl A. Poterack, MD[5]; Timothy A. Miksch, MBA[4]; Richard A. Helmers, MD[3]; David R. Kaufman, PhD[1,3]**

**[1]Department of Biomedical Informatics, Arizona State University, Phoenix, AZ**

**[2]School for the Science of Healthcare Delivery, Arizona State University, Phoenix, AZ**

**[3]Mayo Clinic, Phoenix, AZ, [4] Mayo Clinic, Rochester, MN,**

**[5] Department of Anesthesiology, Mayo Clinic, Phoenix, AZ**

**1.0 Abstract**

Medication reconciliation (MedRec) is widely recognized as a mission critical task across sectors of healthcare. However, there is also evidence to suggest that current systems provide inadequate cognitive support and presents significant usability challenges. The study reported here is part of a largescale effort to characterize EHR workflow in advance of an EHR conversion throughout the Mayo Clinic system. We compared and evaluated two different MedRec interfaces with a particular focus on preoperative nursing assessment at two different sites. The MedRec interfaces differed in their modes of interaction and the ways in which they structured and supported user interaction. The analyses revealed unnecessary complexities that impacted the efficiency and could influence the efficacy of the reconciliation process. Different designs differentially mediate task performance which, in turn, has an effect of mitigating errors for complex cognitive tasks. This study demonstrates the importance of understanding the EHR workflow process in detail for MedRec and studying the process *in situ*. Basic system redesign and better adherence to usability heuristics can lead to systems that minimize cognitive load while maximizing patient safety.

**2.0 Introduction**

Medication errors are a leading cause of adverse drug events with associated death rates estimates of up to 90,000 deaths per year in the US.[1] These preventable events are often due to inaccurate accounting of patient medications listed in the electronic health record (EHR) which have been shown to contribute significantly to adverse drug events.[2] Medication reconciliation (MedRec), a meaningful use requirement, involves a stepwise process of constructing up-to-date medication lists with detailed medication information. Despite the importance of MedRec, task completion in most EHRs are unnecessarily complex and lack intuitiveness.[3] During the MedRec process, various errors can occur such as duplications, omissions, dosing errors, or failures to recognize drug-drug interactions. [4-5]

The MedRec components of EHRs vary considerably. These interfaces are typically complex, carry high levels of cognitive load and can contribute to medical errors[6]. These errors are often attributed to the lack of cognitive support in interface design[6-7]. Several studies have compared performance of the MedRec task on different EHRs. Horsky et. al., compared two existing EHRs in investigating effects of different design concepts on task performance. The comparison showed clinicians made three times as many errors working in EHRs with single column lists, as compared to using a system with side-by-side lists, which offers enhanced visibility. Excessive cognitive effort and reliance on memory (necessitated by screen transitions) was likely a strong contributing factor for lower accuracy of reconciliation[7]. Plaisant et. al. contrasted a conventional interface design with a novel design (Twinlist), based on HCI research. The Twinlist interface uses animations to split information into 5 columns for ease of access, while the control used two side by side lists to display medication information. Evaluation showed that in Twinlist, with its

multi-column design, participants were able to complete MedRec significantly faster than the control, with a substantial reduction in number of clicks.

Mayo Clinic is preparing for the enterprise wide conversion to a common EHR system by launching the ROOT (Registry Of Operations and Tasks) Project to identify current workflows at their sites involving EHRs and other HIT interactions[8]. One of the main goals of the ROOT project is to characterize variations in workflow across different clinics. The work presented in this paper focuses on MedRec performed during the preoperative (PreOp) nursing patient assessment process (i.e., occurring prior to surgery). Specifically, we contrast the use of two different systems at Mayo Clinic settings. The objective of this work is to understand variation in complexity and identify barriers in workflow prior to a large-scale EHR conversion at all Mayo sites.

## 3.0 Methods

The ROOT project employs a broad range of methods including interviews, log file analysis and video ethnography to characterize EHR workflow in surgical settings. In this paper, we report the results of the video capture of nursing assessment of the PreOp process that occurs just prior to the patient being transferred to the operating room. To capture EHR workflow, we employed Morae™ 3.3, a video-analytic software. Clinicians were observed performing EHR tasks in the context of their routine workflow. Morae™ was used to video record participants' EHR-based tasks in different surgical settings. The software captured the participants' screen, a set of analytics (e.g., mouse clicks and web-page changes), and, through the use of a webcam, audio and video recording of the participant's face or hands depending on the foci of interest. In addition, an observer was always present to note other observations.

### 3.1 Settings and Systems

Observations of nurses took place at Phoenix Mayo Clinic hospital (Phoenix, AZ) and at Methodist and Saint Mary's Campus (Rochester, MN). All observations were performed in preoperative care and focused on the PreOp nursing assessment. Video analysis was performed on 17 patient cases which involved seven nurses across sites. At the Arizona campus, the main tool used for charting is referred to as EHR 1. For the purpose of this paper we combined Methodist and Saint Mary's as the Minnesota campus, because the use the same EHR. At Minnesota, the main tool used for charting is referred to as EHR 2.

### 3.2 Data Analysis

Videos were first reviewed for integrity and gaps in time (e.g., where no activity was observed). Videos were then segmented into individual tasks. Once segmented, quantitative and qualitative analyses were performed. The quantitative analyses focused on the analytics of interactive behavior (e.g., mouse clicks, screen transitions). Each individual task was reviewed and mouse clicks and screen changes were recorded for the time of task completion. Qualitative analyses involving narrative summaries (i.e., analysis of episodes in the encounter), cognitive walkthroughs and process models for the MedRec task were performed to obtain a more granular understanding of interactive behavior. Patient narratives included the interactive behavior, length and dialogue for each task involved in the PreOp nursing assessment. The MedRec task was then selected and detailed information about the task was isolated. Cognitive walkthroughs were performed for the MedRec task for the two different EHRs. Subgoals, user actions and system responses were determined and recorded. Process models were created to capture clinicians' cognitive process of completing the MedRec task for the two EHRs.

## 4.0 Results

The results from analysis of video ethnography from three different Mayo clinic sites using two different systems are shown in this section. Figure 1 shows a representation of the interface used for the completion of MedRec. The left schematic represents EHR 1, used in Arizona while the right represents EHR 2, used in Minnesota. In EHR 1, a less crowded interface is used, with a current list of medications (green) and medication details (brown). In EHR 2, there is a current list of medications (green), medication details (brown), and a utilities section (purple) for functions like leaving messages for medications, and reconciling the last dose taken. Interesting differences surfaced between the interfaces regarding navigation, compliance completion and information displayed. In EHR 1, the navigation to the MedRec screen is somewhat simpler. The clinician navigates to the "Orders" section and then clicks on a button marked "Document Medication by Hx", which leads to the schematic seen below for EHR 1. The interface displays a current medication list (blue) and a compliance section for last doses (brown). In EHR 2, to access the screen for reconciliation, the process involves three steps. First, the clinician opens a command window and enters a shorthand of "med list" which directs to a medication home page. From here, the utility button of "Message" is selected and this action brings up the screen seen below for EHR 2. This is where last dosages for medications are added. In the bottom

section of the interface, marked “Utilities” in red, are a panel that allow the clinician to leave a message about a medication, see any changes to orders and most importantly reconcile the last dose of medication

The reconciliation of last doses of medications is similar between the two EHR interfaces. In EHR 1, the medication is selected, and the clinician right-clicks and selects “Add/Modify Compliance”. Once selected, the “Compliance” section opens and a series of drop-down menus for date and time selection appears. Once entered, the date and time populates into the above medication list in a column next to the name. In EHR 2, under the “Utilities” section there is a button labeled “Add Last Dose Taken”. When the clinician clicks, a new window is generated with dropdown menus for date and time selections. Once confirmed, the date and time populates into the “Compliance” section and is saved. Though EHR 2 requires more steps, fewer mouse clicks are needed to reconcile a medication yet the dialogue box results in the more screens. In EHR 1, there is one extra mouse click required, yet the date/time fields can be completed on the same screen as the current medication list.

Displayed medication information also varies across interfaces. In EHR 1, there is a simpler interface with the medication list showing information more relevant to the patient dosage information. In EHR 2, more information related directly to the medication itself is displayed (type of prescription, start date, allergy). One key difference in the patient and medication details is indicators as to whether medications are current, or to be initiated post-operatively. In EHR 1, there is a column specific to status, while in EHR 2, clinicians check the start/end date. Included in medication information is also information about the user completing reconciliation. Confirmation of MedRec completion differs across interfaces, where EHR 2 collects information such as the role of the user completion the action, and the ward in which this list is being verified for. EHR 1 has a simpler interface with fewer actions required, but affords fewer options to record a more comprehensive MedRec documentation.

In this analysis, we contrast two cases of moderate complexity. Patient 5 in Arizona required the reconciliation of 17 medications. The representation of the interface for EHR 1 shows the use of split screen panels to complete MedRec, necessitating fewer screen transitions. However, when trying to reconcile the last dose of a prescribed Albuterol inhaler, there was a misunderstanding between the patient and the clinician regarding the specific medication listed in the EHR. In order to confirm this, the nurse attempted to find details on the medications using a drug information resource available (similar to an infobutton). The clinician first clicks on the medication name from the current medication list and the order details rather than medication details appear. Following this, the nurse right clicks and chooses “Order Information” and the same information appears. Finally, the nurse clicks on “Medication Information” and the needed drug information is displayed. This process added nearly an additional minute to the MedRec process. An additional 12 clicks and nine screen transitions were required to find the desired information. This delay can be contributed to the difficulty to access information due to no consideration to simplify the interface.

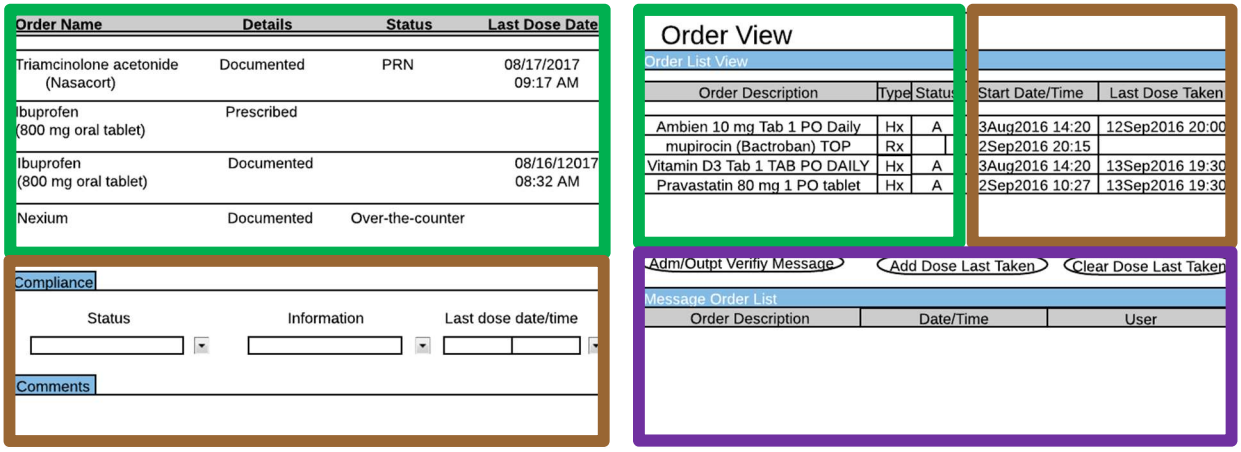


*Figure 1: A schematic Representation of the electronic MedRec task from EHR 1 in Arizona (left) and EHR 2 in Minnesota (right)*

In Minnesota, there was also a case of considerable complexity resulting from incorrect dosage information on Lisinopril. When the incorrect medication is selected, the option to edit is unavailable so the nurse selected the option to document a new medication, creating a new level of complexity and possible source of error. Once in the documentation page, the clinician searched for the medication Metoprolol, also on the medication list, rather than

Lisinopril. This confusion is due to the medication list not being viewable from the documentation window, creating an instance where recall is necessary over recognition. Once the correct medication is selected from a long list of options (around 10), medication details are entered. It is important that the clinician removes any information normally used for prescribing a new medication, such as number of pills, because the purpose of the documentation is for history, not placing a new order. Once completed, the modified medication appears in the current medication list. The final step is for the clinician to remove the incorrectly dosed medication from the current medication list and the new medication is reconciled for the last dose taken.

| | Mean Medications | | Time | Mouse Clicks | Screen Changes |
|---|---|---|---|---|---|
| **Arizona (n=5)** | Mean | 8.8 | 0:02:17 | 36.4 | 6.2 |
| | Standard Deviation | 5.67 | 0:02:36 | 52.86 | 3.77 |
| **EHR 1** | Range | 3-17 | 0:00:10 – 0:06:30 | 2 – 130 | 2 – 12 |
| **Minnesota (n=5)** | Mean | 7.33 | 0:01:26 | 26.4 | 9.8 |
| | Standard Deviation | 5.13 | 0:00:54 | 16.32 | 6.98 |
| **EHR 2** | Range | 3-13 | 0:00:38 – 0:02:48 | 11 – 51 | 4 – 21 |

*Table 1: Means, Standard deviations and ranges of interactive behaviors for Arizona and Minnesota (combined data from St. Marys and Methodist)*

Table 1 shows measures of interactive behavior collected from video ethnography for the task of MedRec. The mean, standard deviation and range for the number of medications per case, the time to task completion and the amount of mouse clicks and screen changes for performing the task is shown below. Results show that the mean time for completion is higher in Arizona subjects with 2 minutes 17 seconds while in Minnesota, the mean time is 1 minute 26 seconds. In terms of mouse clicks, Arizona also had a higher amount with 36.4 while Minnesota has 26.4. The average number of medications for the two sites shows some variation, with Arizona having a mean medication of 8.8 while Minnesota has 7.33. We anticipate that any difference in the number of medications is simply a result of the chance difference in patients on a given observation. Arizona nurses used fewer mean screen transitions at 6.2 as compared to Minnesota with 9.8 screen changes, yet had a higher number of mean mouse clicks at 36.4 as compared to Minnesota with 26.4. EHR 2 includes more interface elements which provide additional functionality and displays medication details (initial order information, medication instructions, etc.). However, there is inefficient use of screen space on the display. As a result, additional widgets such as pop-up windows/dialogue box are used for data entry.

In Arizona (EHR 1), there is considerable variation in the ranges for interactive behaviors. With a range of mouse clicks from 2 – 130 and screen changes 2 – 12, this variation can be partially attributed to case complexity. This specific case had the highest level of interactive behaviors, along with the highest amount of medications to be reconciled at 17 medications. In this instance, the clinicians struggled to access specific medication information, which results in numerous mouse clicks. This difficulty accessing information can possibly be attributed to the lack of ease of information access and the complication of design. The EHR interfaces used for MedRec are crowded and often display pieces of information that are rarely utilized by the clinician. Rather than using screen space to display this information, options to access this information when needed should be used. A

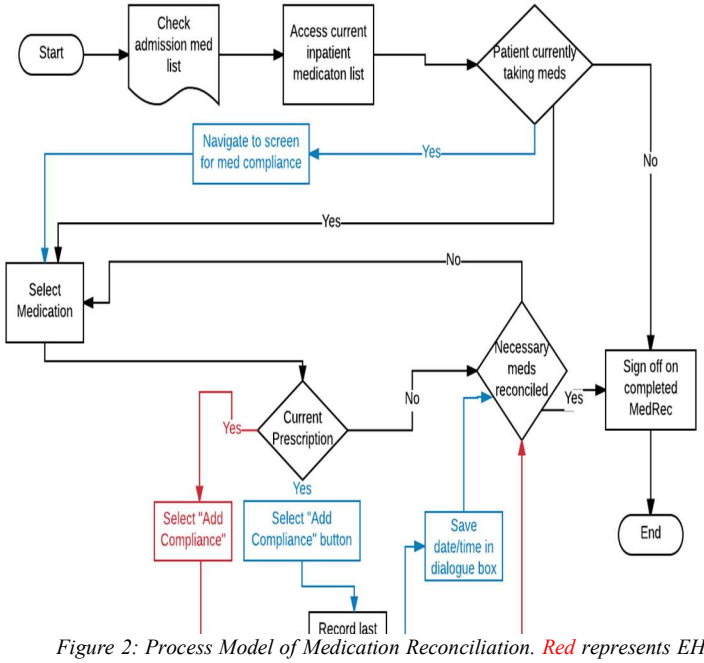


*Figure 2: Process Model of Medication Reconciliation. Red represents EHR 1, blue represents EHR 2*

minimalist design approach that eliminates rarely used information should be considered to reduce the effort necessary to access information. In Minnesota (EHR 2), there is a higher mean screen changes at 9.8, significantly higher than in EHR 1 (6.2). The difference in means can be attributed to a specific problem a clinician experienced when trying to correct an incorrect dosage of a medication listed on a patient's chart. The clinician attempted to correct a medication use to incorrect dosage and experienced difficulty when searching for the medication. When modifying a medication, the current medication list is not viewable which placed a high level of memory load of the clinician. This necessitated a reliance on recall rather than recognition and created an opportunity for error in task of substantial complexity. Figure 2 captures clinicians' cognitive process of completing the MedRec task across both the Arizona and Minnesota sites. The process of determining if MedRec occurs is the same for both EHRs, where a decision is made based off a patient having currently prescribed medications prior to procedure. Once medication status is determined, the first difference in the two systems can be seen in blue. In EHR 2, an extra step is needed to navigate to the medication compliance page to add the last dose taken. In EHR 1, the medication can be selected directly from the inpatient medication list. The second main difference occurs in the cognitive process of adding the last dose of medication taken. Notably, in both interfaces, current medications and medications post-procedure are grouped together. In both interfaces, the clinician must determine whether the medication is a current prescription or not. In EHR 1, the medication can be simply right-clicked and "Add Compliance" selected. The med list screen is split and a dropdown for date and time is used to record the last dose. Once a new medication is selected, the compliance date and time auto-populate. EHR 1 appears to have a less complex MedRec process that removes some cognitive load from the clinician.

| |
|---|
| **Goal**: Complete medication reconciliation |
| Start State |
| **Screen**: Enterprise Order Prescribing Home Screen |
| **Screen**: SurgiNet IView screen |
| **Subgoal:** Find current medication list |
| **Action**: Enter shorthand code |
| **System Response**: full medication list displayed on new screen |
| **Action**: Navigate to Orders Section |
| **System Response:** Screen transitions to page with all orders listed |
| **Action:** Click "Document Medication by HX" tab |
| **System Response:** List of current medications is displayed |
| **Subgoal**: Reconcile medications |
| **Action**: Select medication |
| **System Response**: System highlights medication to distinguish from list |
| **Action**: Click on "Add Dose Last Taken" button |
| **Action:** Right click on medications and choose "Add Compliance" option |
| **System Response**: Pop-up window opens with auto-populated current date and time |
| **System Response**: Bottom of screen shifts to show details for medications |
| **Action:** Nurse adjusts time of last dose based off of patient response and saves |
| **System Response:** Date and time entered saved under "Dose last Taken" column |
| **System Response**: Date and time entered are saved |
| **Subgoal:** Verify medications |
| **Action:** Nurse clicks to apply verification message |
| **Action**: Nurse clicks "Document History" button |
| **System Response:** Pop-up window with dropdown menus for verification information opens |
| **System Response**: System saves reconciled medication list |
| **Action:** Nurse enters appropriate information and saves |
| **System Response:** System saves message and marks medication list as reviewed |

*Table 2: Cognitive walkthrough of MedRec as performed in EHR 1 (blue) and EHR 2 (red). Black text refers to steps common to both.*

A cognitive walkthrough for MedRec was performed for EHR 1 (blue) and EHR 2 (red) as seen in Table 2. The main goal, completing MedRec, were essentially identical across both systems and settings. Both EHRs began in their start state with three main subgoals: Find current medication list, reconcile medications and verify. Though the subgoals were identical, there was a difference in the processes. The cognitive walkthroughs were used in conjunction with the process models to show not only the cognitive process clinicians go through when reconciling medications, but the goals and interface actions that drive task completion as well. Together, these qualitative analyses allowed for a more comprehensive characterization of interaction complexities involved in MedRec. The reconciliation process differed in EHR 2, where the interface necessitated more screen transitions. In EHR 2, the "Add Compliance" button had to be chosen from a selection of utility buttons. Once selected, a dialogue box appeared with the dropdown menus for adding compliance. Once information is entered, the save button had to be selected on the dialogue box to populate the compliance date and time into the current medication list. If this step was not completed, the dialogue box would not close and the compliance would not be saved. Though this process was more complex, it offered a deeper layer of security and may reduce the number of errors occurring.

## 5.0 Discussion

This study demonstrates the importance of understanding the EHR workflow process in detail for MedRec and studying the process *in situ*. MedRec is crucial, yet complex procedure to improve patient safety that carries high levels of risk. There is ample evidence to suggest that this process is both complex and inefficient[4]. In order to optimize the process, the workflow process needs to be both understood and well integrated. We have gained considerable knowledge from studies contrasting MedRec systems. However, here we sought to contribute to a large-scale EHR

conversion process. One important limitation is that it is not possible to control for routine variation in complexity of the task. Here we contrasted two different systems which incorporated somewhat different approaches to MedRec. Though EHR 1 has a more minimalist approach and requires fewer interactive behaviors, there is less information collected and displayed about the MedRec process. EHR 1 had fewer screen changes (mean 6.2 vs 9.8), whereas EHR 2 had a lower mean mouse clicks (26.4 vs. 36.4). The mean time to task completion was higher in EHR 1 at 2:36 though it utilized a more minimalist interface.

Usability heuristics such as minimizing memory load, aesthetic and minimalist designs and recognition rather than recall need to be carefully considered in interface design for this task. These considerations provide an informed idea about future system implementation in unison with the upcoming Mayo EHR conversion. At a top level, the use of minimalist design is key to optimizing interfaces in both EHRs. In EHR 2 when attempting to add medication compliance, navigation from the main screen to a compliance screen is required. A text field for compliance which is readily available on the main display would be preferable to generating a pop-up window and allows for fewer screen transitions. Although the panel affords access to additional functionality (use was not observed), the extra effort necessary for navigation and data entry in EHR 2 may be better supported by a minimalist design. The panel appears to include irrelevant or rarely needed information and diminishes the relative visibility of relevant information[9]. Other heuristics should be considered such as emphasizing recognition rather than recall to minimize the memory load on clinicians. We observed the impact of having to juggle the screens, adding a burden to cognitive load and resulting in error. The system user's memory load could be minimized by making objects, actions and options more readily visible. In EHR 2, the current medication list is not viewable when attempting to edit a new medication from the order entry dialogue box. The user should not have to recall information from one part of the dialogue to another.

Plaisant et. al.[8], demonstrate that through consideration of user-centered design elements, problems in design and workflow can begin to be identified, and new interfaces can significantly improve performance, safety and maximize efficiency clinical implementation. In order to understand these interaction complexities involved in the MedRec task, a close scrutiny of the system interfaces must be performed while considering both cognitive support and usability principles. Using these comparison methods allows for more thorough identification of design constraints and workflow problems[9]. These interface comparisons have proven necessary in that different designs differentially mediate task performance which, in turn, has an effect of mitigating errors for complex cognitive tasks.

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