

Design Guidelines for Ensuring Timely Management of Medical Orders

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ABSTRACT

Medical professionals need to handle the orders for their patients. Many steps can go wrong in the result management process and current systems fail to solve the missed results problem. We introduce our design guidelines for rich tabular displays to ensure timely medical care: (i) show pending results, (ii) prioritize by late and lost status, (iii) clarify responsibility, and (iv) embed actions. We evaluated the benefits of applying the first two guidelines in a user study, which showed very promising results. These guidelines can be applied to a variety of other application domains.

Author Keywords

Electronic health records (EHRs); result management; situation awareness; health care; table design

ACM Classification Keywords

H.5.1. Information Interfaces and Presentation: User Interfaces

General Terms

Design

INTRODUCTION

“Sue hurts her leg in a bad fall. Her primary care physician orders an X-Ray, one of the dozens of orders he writes that day. She chooses to schedule her appointment at an independent radiology center near home. She remembers to go the next day, and a technician takes the images. Next, the radiologist is supposed to review the images and write a report which will be faxed back to the primary care physician, who should review the result and follow-up with Sue, if needed. However, something goes wrong and the physician never sees the results. He has an Electronic Health Record (EHR) system but he does not notice that he never received Sue’s results. Sue loses her leg since the fracture was never treated.” Unfortunately, this is a real story. Many things can go wrong in this complex process with multiple steps, actors, and responsible parties, and patients are physically harmed when

results of medical orders (e.g. lab tests, imaging studies, referrals to specialists) are mishandled or lost [8]. Patients can become sicker or even die. In fact, failure to follow up on abnormal results is one of the most frequent causes of medical malpractice litigation in outpatient medicine [13]. It impacts efficiency and effectiveness of treatment, patient safety, and overall satisfaction [11].

There are no established standards as how best to manage medical results [17]. A study of current medical information systems used for tracking discovered there were interface and logic errors in results routing, physician records, system setting interfaces, and system maintenance tools [18]. During our interviews, we saw environments where needed results are received in a timely and reliable fashion (e.g. emergency rooms in hospital with all test facilities in house); while others reported very high rates (20%) of late or lost results. We observed physicians keeping paper cheat sheets, while staff – and patients – reported spending hours on the phone tracking what went wrong. Even when physicians have reliable systems, medical staff do not routinely check the status of all pending orders [5]. Better designs to help medical staff such as physicians or clinic managers who are responsible for timely result management could bring large benefits.

Lists remain the most common way to manage daily work [2] so our focus is on interactive rich table displays to show the progress of orders. In our prototype, rich tables are generated by the MSTART (Multi-Step Task Analyzing, Reporting, and Tracking) system from a workflow model that defines processes, composed of multiple steps that are associated with possible user actions [16]. Rich tables were refined by conducting dozens of iterative design reviews with medical professionals. We devised the following guidelines to improve the timely management of medical orders: (i) show pending results, (ii) prioritize orders and results by late and lost (i.e. very late) status, (iii) clarify responsibility, and (iv) embed actions. The first two aim to foster users’ attention and the last two allow users to rapidly take action. Our guidelines extend on Stephen Few’s table design recommendations [7] and Microsoft’s Common User Interface design guidance [10] for medical systems. Finally, a user study was conducted to formally compare the first two of these guidelines in the rich table to the common interface in-use today for reviewing results. We learned that our guidelines can help reduce the problem of missed results.

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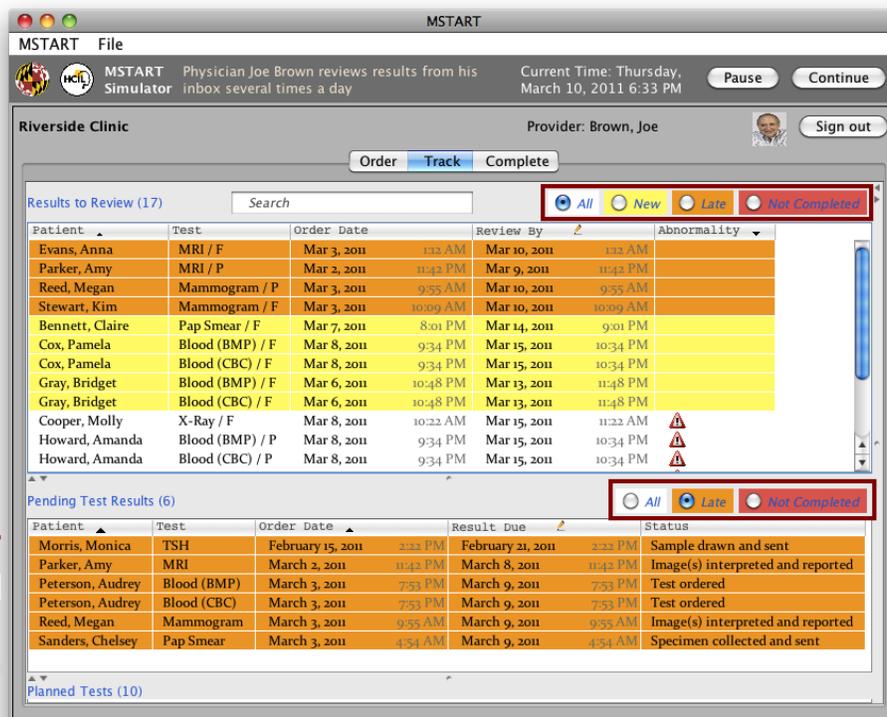


Figure 1. Rich tabular displays as seen by a physician. Rich tables adhere to our design guidelines. Hovering over reveals informational tooltips.

RELATED WORK

To the best of our knowledge, the state-of-the-art for medical order tracking is a system called Results Manager by Partners Healthcare [14]. Results Manager is limited by not showing late results and impediments to taking rapid actions on them. Other clinical event notification systems [12] remind physicians to follow up on results. Research has indicated that such systems generate many undesired alerts and cause clinician alert fatigue; this may result in the clinician either bypassing or missing the important alerts [15]. Other researchers applied workflow management techniques to clinical situations [3]. These models assist in optimizing or testing workflows in the context of an ideal environment, while we focus on what can go wrong in the real world.

There are many principles that could be learned from well-designed alert systems. Researchers have built tools to support organization of users' daily tasks and roles [2]. These systems generally display tasks in chronologically-ordered lists [6] and remind users about their pending tasks and users switch between screens to complete the tasks. Such interruptions have been found to reduce awareness [4, 9]. In the medical domain, further interruptions add to the risk of error. Information visualization research has applied situation awareness theory [1] but requires users to focus on the visualization to discover anomalous behavior. The medical workflow is more dynamic and time critical.

DESIGN GUIDELINES

Our guidelines come from the perceived shortcomings of existing EHR interfaces. In most systems, physicians see a list of results that came back (either for all patients, or per patient), which serves as a reminder to review results. Pending orders are not visible (unless physicians read the details of the individual patient records or use clumsy reporting tools) so physicians are forced to remember orders they have placed. Systems have no notion of expected latency between order and results. Result lists are sorted by arrival date, with the newer ones at the bottom. If an expected result is not there, there is no way to know what could be wrong. The only resort is to get on the phone and track the order down. Once results have been seen, there is no mechanism to ensure the follow-up is complete.

Our design guidelines are as follows:

Show Pending Results

Whether looking at results of all patients or only one patient, the table should provide access to arrived results, pending orders, and planned orders. Figure 1 shows an example for all the orders of Dr. Brown. Results that have returned are listed at the top in "Results to Review", while orders that have not returned to the physician are shown under "Pending Test Results". Orders that have been ordered already but will take effect in the future (e.g. a mammogram at patient's fiftieth birthday) can be accessed in the "Planned Tests" (collapsed here). On the date for when the planned orders were placed, orders automatically move from planned to the pending ta-

ble. As the results of pending orders arrive, the entry in the pending table moves up to the topmost table. Returned results are removed once the physician has reviewed the results and confirmed that the follow-up is complete.

Prioritize by Late and Lost Status

Our prototype employs an underlying result management workflow model that assigns a normal and a maximum duration to each step in an order. For example, a patient might be given three days up to a week to schedule and go to get an X-Ray. We can then calculate a normal and maximum expected duration along each step of the process e.g. one to three weeks (and physicians can overwrite the normal duration at order time if they want rapid returns). After the normal expected duration – reflected in the “Result Due” date – the order is determined late and shown orange (e.g. an X-Ray still being processed on the tenth day). After the maximum time has passed, the order is considered lost or not completed (shown as red) and the order may have to be repeated or cancelled. The time to complete each step can be logged for later retrospective analysis to inspect bottlenecks as well as the best and worst performers, and adjust normal and maximum expected durations.

The step to be completed by physicians also has a normal and maximum duration. The result list at the top has a “Review By” date and physicians’ work might be late (orange) or not completed (red). Orders that have not been looked at yet are yellow, while the white ones have been reviewed but the follow-up is not complete yet. The color legend acts as a filter, e.g. the pending table is pre-filtered to show only severe (late and lost) cases. Lateness information is available to all users of the system. For example, clinic managers can track if physicians are following up on their orders on-time or not, and can forward results to alternative physicians if needed, e.g. in case of physician illness. Due dates can be modified directly in the table, if appropriate.

Results are sorted first by lateness, secondly by whether they have been seen, thirdly by abnormality status (shown with a warning sign), and finally by patient name to group results of the same patient together. Pending orders are sorted by lateness first, then by patient name.

Clarify Responsibility

Pending orders have a column for order status (see Figure 1) indicating the last completed step. A click on the row brings a popup menu (Figure 2) showing who is currently responsible for the progress of the order and the expected completion time. For late orders, there is information on who to call to speed up the process. When the order is considered lost, a reorder button appears.

In addition, the popup enumerates the completed steps in chronologically descending order. The first step of each pending order is the patient scheduling the exam so the patient is the first responsible person (see the last item under “Completed steps” in Figure 2). The next steps involve the outside facility processing the order (see the first two bullets under “Completed steps” in Figure 2). The letter ‘P’ or ‘F’ in the

results table distinguishes preliminary from final results (Figure 1). Such results appear in both pending and results tables because although the facility generates an initial report for physicians to see, the order has not been finished processing by the facility and the outside facility is still responsible for finalizing the report.

Embed Actions

While some results require careful review in separate screens with access to the patient history, there are many situations where actions can be taken rapidly, e.g. for normal routine results in a general practitioner office. We propose to allow users to take action within the result list.

Possible actions depend on the role of the logged in user. When physicians or residents click on a result, the result report and simple follow-up actions appear side-by-side, below the row (Figure 3). If more information is needed to deal with a complex case, a double-click will open the patient record. In other cases, the panel of common simple actions is easily accessible and stays on the screen until users indicate either they need to come back and review further later (the result remains in the list and is colored white), or that the follow-up is complete (the result is removed from the list and goes to a separate “Complete” panel in Figure 1).

USER STUDY

To quantify the benefit of the first two guidelines (showing pending orders and prioritization by late and lost status), we have begun a within-subjects study in which participants took on the role of physicians and answered questions about the timeliness of orders using three interface variations. The baseline interface consisted of a single list of chronologically-ordered results, while the second added a separate list for pending orders, and the third, prioritized the pending orders by lateness status. Order of interface appearance was counterbalanced and assigned randomly. Participants were given five minutes to read and remember a list of twenty orders for their patients and normal and maximum durations to complete different types of orders. They were then asked to perform a distraction task for five minutes (so that they did not remember the details). After a short explanation of the interface, participants were asked to identify which orders were late (i.e. longer than normal) and which were lost (exceeding procedure time limits). We recorded the time to arrive at the correct answer and the number of corrections they had to make. In addition to the \$10 compensation, a bonus \$10 was offered to the best performers in each interface.

The results (Figure 4) suggest that showing pending results can decrease the time needed to answer the questions by more than a half and that prioritization of the results helps even more. We ran a repeated measures one-way ANOVA (three treatment levels) with pairwise comparisons using Holm adjustment method. Differences are statistically significant ($p < 0.01$) and post-hoc paired t-tests establish differences between the interfaces: baseline to second ($p < 0.01$), baseline to third ($p < 0.01$), second to third ($p < 0.01$).

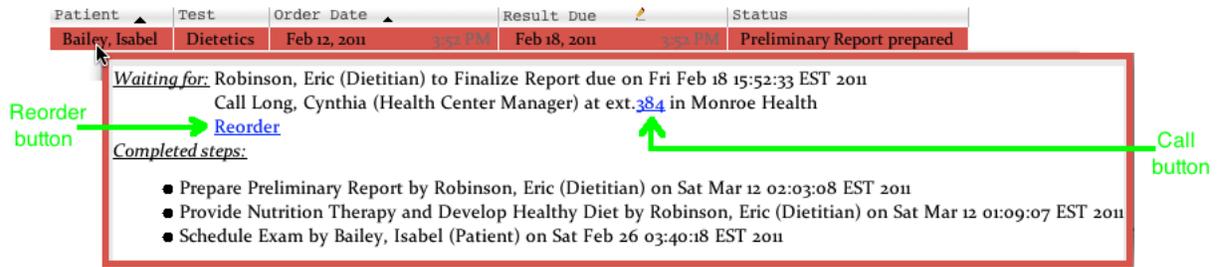


Figure 2. Popup menu for pending orders.

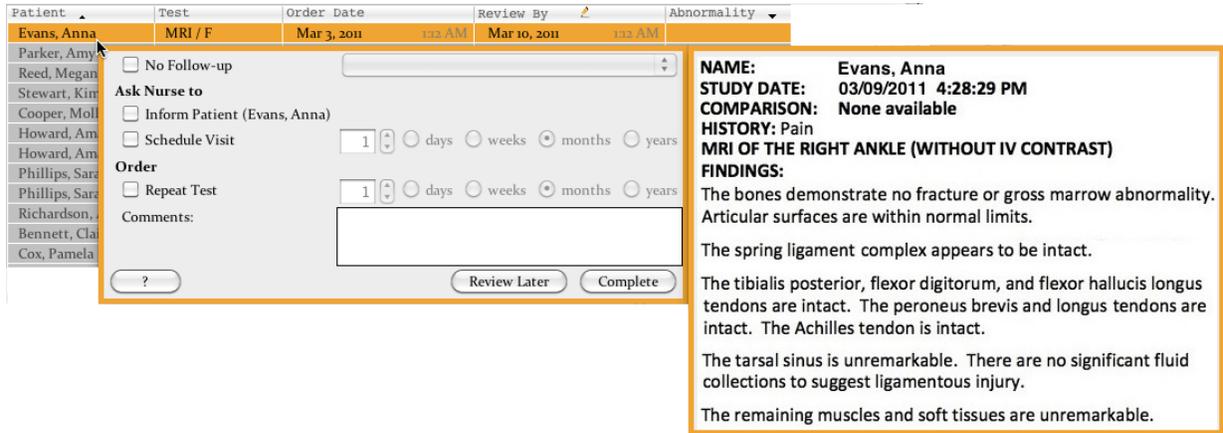


Figure 3. Interactive action panels facilitate rapid completion and results appear on the right.

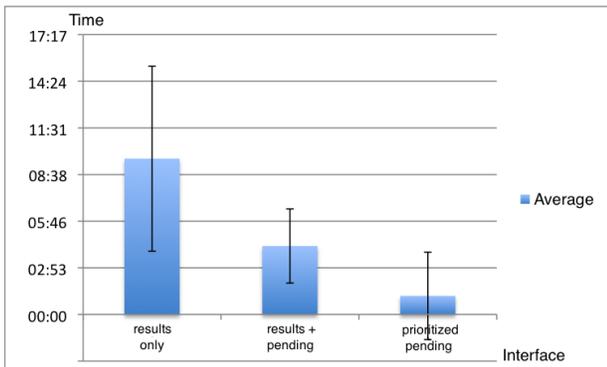


Figure 4. Results of our user study (with eighteen participants).

DISCUSSION

The implication of these results is that applying our design guidelines can provide great help for busy medical workers. As improved systems reliably report delayed orders and effectively guide clinicians to act on them, they will spend less time sorting out the issues in the process. When physicians manage their results more promptly, they will also be able to provide better care for their patients.

These guidelines are also generalizable to tracking interfaces built for other processes where various responsible parties collaboratively handle different steps, being separated by time and distance. Examples include but are not limited to the software development cycle, paper-review process in academic journals, and business processes such as the return

merchandise authorization process in the electronics industry and the internal supplier agreement process in IT companies.

There were some limitations to our study. It was difficult to simulate a real environment in an hour-long study. Our distraction task separated the ordering from the reviewing step but did not include distractions that may happen during order or review time. We believe the study results could have been more prominent if there were more distractions but it would have overwhelmed our participants. Although we offered a prize to increase motivation, the participants did not develop any strategies to remember the orders and as the study progressed, they realized attempting to memorize orders was useless and they gave up completely. This also confirms what we saw in the clinics where physicians made extensive use of cheat sheets to remember their orders.

CONCLUSION

Missed results is a very serious problem. We propose our design guidelines to ensure timely management of medical orders. The results of our user study confirm that better designs can have a dramatic effect on the performance of such systems. In addition, clarifying responsibility and embedding actions in the result tables can further reduce the problem of missed results. We believe that our guidelines can offer improvements to similar workflows. We are also working on interfaces that facilitate retrospective analysis of the performance data, to identify the bottlenecks as well as the best and worst performers.

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