Development of an Effective User Interface for a Computerized Laboratory Alerting System

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Abstract

A computerized medical decision-aid (CMDA) must have a good user interface. The quality of the user interface impacts directly on the effectiveness of the CMDA. At LDS Hospital, we have developed a computerized laboratory alerting system (CLAS) to monitor hospital patients for life-threatening conditions indicated by patient laboratory test data. One of the challenges faced in developing CLAS was designing an effective user interface. Though designed in close cooperation with users, evaluation of CLAS' user interface pointed out problem areas.

Originally, alerts were indicated by posting the alerting patient's room number on computer terminals, and were acknowledged on terminals by clinician alert review. Data on this interface showed a 41.4% acknowledgement rate with an average acknowledgement time of 38.7 hours. These figures were improved to a 3.6 hour acknowledgement time with 94.6% acknowledgement by integrating alert acknowledgement with routine review of patient laboratory test values, and to a .1 hour acknowledgement time with 100% acknowledgement using a flashing light to indicate the presence of an alert. A survey of CLAS users showed that 50% found the system "very" or "frequently" useful. With CLAS II, an expanded and improved version of CLAS, we have modified the user interface further to allow alerts to be sent directly to nurses via patient-specific digital pagers rather than to computer terminals.

1: Introduction

Though numerous articles describing computerized medical decision-aids (CMDA's) have been published, some observers have felt that the impact of these systems has been largely unimpressive. Shortliffe [1] suggests that the ability of a CMDA to give "good advice" is not enough. He states that inattention to human factors (accessibility, mode of interaction, ease of use, speed, and the psychology of human-computer interaction) is the main reason that many CMDA's have failed to gain acceptance or to impact medical care.

From Shortliffe's analysis, it would appear that the ideal CMDA must have a good user interface as well as enhance patient management capabilities. One class of CMDA which potentially fills these requirements is that of computer tools used to monitor and remind [2-4]. These tools generally operate automatically and enhance patient management by reminding of potential hazards, automating repetitive tasks and serving as back-up or fail-safe mechanisms to protect against human error.

Because of the automatic nature of these CMDA's, the main issue an effective user interface must address is that of communication. What is the most effective method for relaying reminders (alerts) to clinicians? How can the CMDA know when an alert has been received? Answers to these questions (though they may vary according to the clinical setting and the nature of the CMDA) are crucial, as they will affect speed, accessibility and mode of interaction and will have a significant impact on how the CMDA is perceived by end-users.

For over 20 years, ongoing efforts have been made at LDS Hospital to develop a comprehensive medical information system (HELP) [5]. The capabilities of HELP have allowed

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development of CMDA's to monitor and interpret patient data and notify clinicians of important items. One such CMDA is a computerized laboratory alerting system (CLAS) designed to monitor hospital patients for the presence of life-threatening conditions (indicated by patient laboratory test data) and to notify clinicians so that appropriate treatment can be more rapidly instituted. Data gathered prior to CLAS implementation showed that 11.4% of all hospital patients experience one or more of these life-threatening conditions during their hospital stay.

One of the challenges faced in developing CLAS was designing an effective user interface. The user interface had to encompass both alert feedback (relaying alerts to nurses and physicians), and alert acknowledgement (letting CLAS know that a nurse or physician had received an alert). In developing CLAS's user interface, we endeavored to take human factors into account, working closely with nurses and physicians to make CLAS fit their needs. However, evaluation of CLAS's user interface pointed out areas needing improvement. This provided the impetus for experimenting with modifications to the original interface, and for a new interface design which is being implemented as part of CLAS II--an improved and expanded version of the original CLAS. Development of the architecture and medical knowledge base of the original CLAS system has been described in detail elsewhere [6-7].

2: Methods

2.1: Background

LDS Hospital is a private 520-bed tertiary care facility which is part of the Intermountain Health Care (IHC) hospital system. It is a teaching hospital associated with the University of Utah College of Medicine, and has more than 300 private physicians on staff. The computer facilities at the hospital include a Tandem Risc R mainframe, twelve Charles Rivers minicomputers, over 1200 "smart" terminals, and several Novell networks. Each nursing division within the hospital has at least four terminals and two printers located at the central nursing station, two terminals at smaller satellite stations, and a terminal at each patient bedside. At the time the original CLAS interface was implemented, bedside terminals were installed only in the ICU's and on one general nursing floor.

2.2: *Initial Development of the CLAS User Interface*

The main issues which had to be addressed in designing the CLAS user interface concerned communication: 1) Who should receive alerts?, 2) To what physical location(s) should alerts be sent?, 3) How should the presence of an alert be signified?, and 4) How should receipt of an alert be acknowledged?

After consulting with nurses and physicians, it was decided to communicate alerts to nurses rather than to physicians because of the nurses' continuous close physical proximity to patients and to hospital terminals. Physicians would also be able to receive alerts when they were in the hospital and near a computer terminal.

It followed that the physical location to which alerts should be sent was the nursing unit where the alerting patient was located. CLAS' architecture permitted alerts to be transmitted to any terminal within the hospital. Alerts were routed by patient room number to all computer terminals at the central and satellite stations of the appropriate nursing unit and to the patient's bedside.

The presence of an alert was indicated by display of the alerting patient's room number in the lower left hand corner of the computer terminal screen. This method of display was chosen over other possibilities (such as displaying alerts in reverse video, having the terminal beep and display the alert, or having the alert flash on the terminal for a fixed period of time) because of nurses' concerns that: 1) alerts be presented unobtrusively, especially at the patient's bedside, and 2) the potential inconvenience of an alert message appearing on-screen while a computer

terminal was in use be avoided.

Though CLAS could theoretically have fulfilled its alerting function by merely identifying and transmitting alerts, it was important to get some kind of acknowledgement in order to evaluate the effectiveness of the user interface and make improvements if necessary. Acknowledgement of alerts also benefited hospital staff by providing a way for clinicians to determine whether an alert had been received and acted upon. Because HELP (which CLAS is based on) is menu-driven, it was felt that adding an option to HELP's main menu would be a convenient way to provide for alert acknowledgement. Choice of the Lab Alert option brought up the Lab Alert menu which allowed display of both current and acknowledged alerts for a single patient, or for all patients on a given nursing division. Users were given the option of generating a printed report of alerts. Alerts were considered to have been acknowledged once they were reviewed on the computer terminal. When an alert was acknowledged, the room number was erased from the bottom left hand corner of the terminal screen.

2.3: Experimental Modifications of the Original CLAS User Interface

After CLAS was implemented and a two-month nurse training period was completed, data were collected on the effectiveness of the user interface. These data led us to experiment with two different mechanisms for improving the interface, one designed to more effectively signify the presence of an alert, and one designed to streamline the way in which alerts were acknowledged. Data on the effect of each of the mechanisms was collected and analyzed.

The first mechanism we experimented with was installation of a flashing yellow light at one of the central nursing station terminals on a single nursing unit. The light was specially built to be activated and deactivated by codes transmitted as part of the alert message. When an alert message was sent to the computer terminal to which the flashing light was attached, the light was activated. Once the alert was acknowledged, a code was transmitted to deactivate the light.

The second mechanism we experimented with was integration of alert acknowledgement with laboratory test result review. The presence of an unacknowledged alert was still indicated by the display of the alerting patient's room number in the bottom left hand corner of the terminal screen. Receipt of an alert was still acknowledged by review of the alert on the computer terminal. However, clinicians did not have to notice the room number on the terminal and then choose the Lab Alert menu option to review an alert. Any current alerts on a patient were automatically displayed to the user whenever the user chose to review the alerting patient's laboratory test data. This mechanism was chosen because CLAS generated alerts based on laboratory test data, and because review of laboratory test data on the computer terminal was an established part of the patient care process within our hospital.

2.4: Design of the CLAS II User Interface

We are currently in the process of implementing the user interface for the CLAS II system. The original CLAS was disabled due to major software changes within HELP. Before CLAS was disabled, an evaluation of its effect on patient care showed an increase in the percentage of alerting patients receiving appropriate care for alerting conditions (50.8% pre-CLAS vs. 62.5% post-CLAS, $p < 0.05$). These results motivated us to design and implement CLAS II using the capabilities of the upgraded HELP medical information system.

CLAS II's user interface incorporates many elements of the original CLAS user interface, but addresses the questions of how alerts are best communicated to nurses and how alerts should be acknowledged differently. The interface was designed in close cooperation with the hospital's nursing staff, and is an attempt to devise the most effective interface possible within the hospital's existing computing structure and the nurses' existing patient care routine.

The CLAS II user interface is designed to transmit alerts directly to the nurses caring for alerting patients via patient-specific digital pagers. Each nurse on the nursing unit carries a

digital pager. Digital pagers are assigned to nurses at the beginning of their shift. Ward clerks are responsible for keeping a current computer record of which nurse is caring for which patients and carrying which digital pager. When an alert is generated, an alert message is transmitted by a direct line to the Data General minicomputer system which controls all nursing digital pagers. Based on the alerting patient's room number, the nurse caring for the patient is identified and the alert message is transmitted to that nurse's digital pager. The alert message (up to 20 characters) is displayed on the digital pager at the time the nurse is paged. The nurse can then acknowledge the alert by going to a terminal and logging on to the alerting patient (using a function key). This brings up a window on the terminal screen which displays a fuller version of the alert message and gives the nurse the option of acknowledging the alert. If an alert is not acknowledged within 30 minutes of its original transmission to a nurse, the alert message is again transmitted, this time to the digital pager carried by the charge nurse on the nursing unit where the alerting patient is located. Figure 1 illustrates the functioning of the CLAS II user interface.

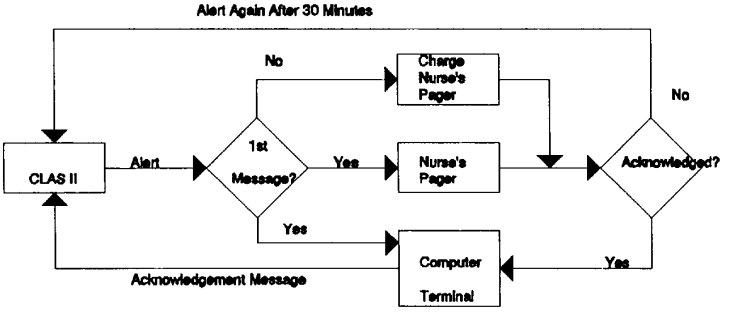

Fig. 1 Functioning of the CLAS II User Interface

2.5: Data Collection

Data on the effectiveness of the original CLAS user interface were collected during an eight-month period. Each time an alert was acknowledged, information on the alerting patient, the type of alert, the time the alert was posted on the computer terminal, and the time the alert was acknowledged was sent to a special data collection file. During the last two weeks of data collection, alert acknowledgement was altered slightly to ask for the user's opinion of the usefulness of CLAS. User's opinions were captured by inserting a short questionnaire into the alert acknowledgement screen which was displayed at the same time that an alert was displayed for acknowledgement. The user was given a list of possible responses to choose from, and the information captured was sent to the data collection file along with information on alert acknowledgement. Data on the CLAS II interface are being collected in the same way as data on the original CLAS user interface. CLAS II data collection will be completed in June, 1993.

For CLAS, data were analyzed by first downloading data from the data collection file (located within HELP) to a personal computer and then using the Lotus 1-2-3 spreadsheet program to tabulate the findings. CLAS II data will be analyzed by the same method.

3: Results

Table 1 summarizes the data collected on the CLAS user interface. The effectiveness of the interface was judged by the time interval between alert posting (on computer terminals) and

alert acknowledgement. Initially, only 41.4% of all alerts were acknowledged with an average of 38.7 hours until acknowledgement. These figures where improved both by using a flashing light (one nursing unit only) to indicate the presence of an alert and by integration of alert acknowledgement with routine review of patient laboratory test values. Data on the flashing light showed that 100% of the alerts were being acknowledged within an average time of 6 minutes. Data on alert acknowledgement/laboratory result review integration showed that alerts were acknowledged 94.6% of the time with an average acknowledgement time of 3.6 hours.

Table 1
Data on Effectiveness of CLAS User Interface

	Acknowledgement Time (avg. hours)	Percent Acknowledged
1. Original User Interface (March 24 to May 3)	38 .7 ± 31.8	41.4
2. With Flashing Light (May 28 to August 10)	.1 ± 0.2	100.0
3. With Alert Acknowledgement/ Laboratory Review Integration (August 14-28)	3 .6 ± 6.5	94.6

For a two-week period in December, data were collected on users' perception of the value of CLAS. Users were asked to rate alerts as: 1--very useful, 2--frequently useful, 3--sometimes useful, 4--seldom useful and 5--not useful. Results of the survey are summarized in Table 2. Of 78 respondents (all users during the data collection period), CLAS was rated very useful by 25.6%, frequently useful by 24.4%, sometimes useful by 34.6%, seldom useful by 7.7%, and not useful by 7.7%. When results of the opinion survey were analyzed according to the class of user, 30.5% of nurses found CLAS very useful, 27.1% found it frequently useful, 25.4% found it sometimes useful, 8.5% found it seldom useful and 8.5% found it not useful. For physicians, 10.5% found CLAS very useful, 15.8% found it frequently useful, 63.2% found it sometimes useful, 5.3% found it seldom useful, and 5.3% found it not useful. Average response value for the two week period was 2.5, corresponding to the midpoint between "frequently useful" and "sometimes useful."

Table 2
Data from CLAS Opinion Survey (78 Respondents)

Users	Very Useful	Frequently Useful	Somewhat Useful	Seldom Useful	Not Useful
Nurses	30.5%	27.1%	25.4%	8.5%	8.5%
Physicians	10.5%	15.8%	63.2%	5.3%	5.3%
All	25.6%	24.4%	34.6%	7.7%	7.7%

4: Discussion

Data collected on the original CLAS user interface help to illustrate the importance of human factors issues in the design of CMDA's. The original user interface required clinicians to develop new habits to use the system. Clinicians had to make a point of periodically checking the computer terminal screen to see if a room number was displayed. Acknowledgement of alerts required accessing a special menu option on the terminal, and several minutes could pass before the acknowledgement process was complete. These factors contributed to the low alert acknowledgement rate and long acknowledgement time of the original user interface. It is informative that neither we, as designers, nor our nurse and physician consultants were able to fully recognize and gauge the impact of these aspects of the user interface until after CLAS had

been implemented clinically and was in daily use.

Though both experimental modifications of the CLAS user interface improved the number of alerts acknowledged and shortened the acknowledgement time, both also had disadvantages. The flashing light was effective (average acknowledgement time of 6 minutes) but unpopular with the nursing staff (nurses eventually disabled the light). Alert acknowledgement/laboratory review integration resulted in an average acknowledgement time of 3.6 hours which, though a great improvement over the original 38.7 hour acknowledgement time, was not adequate for alerts on truly life-threatening conditions.

Despite these drawbacks, we were pleased that users of CLAS had a favorable view of the system. We were also pleased that a number of alerts were acknowledged by physicians, since such acknowledgement meant CLAS was, at least some of the time, reaching those ultimately responsible for the care of alerting patients. It is interesting, however, that nurses had a more favorable view of CLAS (30.5% of nurses found the system "very useful") than physicians (10.5% of physicians found the system "very useful"). This result may reflect physicians' limited use of CLAS or the differing roles which nurses and physicians play in patient care.

One of the main problems with the original CLAS user interface was that users had to be actually at a computer terminal to receive an alert message. In the course of normal patient care, both nurses and physicians spend much of their time elsewhere. Laboratory alerting systems similar to, and implemented after, the original CLAS have not been able to overcome this problem. One of these, implemented at Cedar-Sinai hospital in Los Angeles, posted alerts at central nursing station and bedside terminals in the same way CLAS did [8]. Another, implemented at Beth Israel Hospital in Boston, made use of electronic mail to send alerts to physicians [9]. We believe we have overcome this problem in the user interface we are implementing as part of CLAS II.

The CLAS II interface uses digital pagers to notify nursing staff of alerts. The interface allows the computer to identify the nurse caring for an alerting patient and to route the alert message directly to that nurse via a digital pager. This means that nurses can receive alerts in any location within the hospital as soon as the alerts are generated without having to modify their normal patient care activities. Nurses then use their clinical judgement to determine whether a physician should be notified. Alert messages are also sent to computer terminals where they can be reviewed and acknowledged by nurses and physicians. In addition, we are taking steps to ensure that alert acknowledgement is fast, convenient, easy to use and integrated into the tasks which nurses and physicians routinely perform.

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