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Human factors approach to evaluate the user interface of physiologic monitoring

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Abstract

Background: As technology infiltrates more of our personal and professional lives, user expectations for intuitive design have driven many consumer products, while medical equipment continues to have high training requirements. Not much is known about the usability and user experience associated with hospital monitoring equipment. This pilot project aimed to better understand and describe the user interface interaction and user experience with physiologic monitoring technology.

Design: This was a prospective, descriptive, mixed-methods quality improvement project to analyze perceptions and task analyses of physiologic monitors.

Methods: Following a survey of practice patterns and perceived abilities to accomplish key tasks, 10 voluntary experienced physician and nurse subjects were asked to perform a series of tasks in 7 domains of monitor operations on GE Monitoring equipment in a single institution. For each task analysis, data were collected on time to complete the task, the number of button pushes or clicks required to accomplish the task, economy of motion, and observed errors.

Results: Although 60% of the participants reported incorporating monitoring data into patient care, 80% of participants preferred to receive monitoring data at the point of care (bedside). Average perceived central station usability is 5.3 out of 10 (ten is easiest).

Conclusions: High variability exists in monitoring station interaction performance among those participating in this project. Alarms were almost universally silenced without cognitive recognition of the alarm state. Education related to monitoring operations appeared largely absent in this sample. Most users perceived the interface to not be intuitive, complaining of multiple layers and steps for data retrieval. These clinicians report real-time monitoring helpful for abrupt changes in condition like arrhythmias; however, reviewing alarms is not prioritized as valuable due to frequent false alarms. Participants requested exporting monitoring data to electronic medical records. Much research is needed to develop best practices for display of real-time information, organization and filtering of meaningful data, and simplified ways to find information.

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Keywords: Central station; Bedside monitoring, human factors in monitoring; Usability; User interface; User experience

Introduction

As technology has proliferated in modern society, consumers have developed an impressive level of proficiency for using technology. Ubiquitous technology in smart phones, personal computers, and consumer electronics has changed the user's expectations for performance and integration of technology in our daily lives at work and home [1]. Intuitive design and usability have become expected features of consumer electronics, particularly in the interaction design of such technologies [2]. Although the Food and Drug Administration has guidance for the application of human factors and usability engineering to optimize medical device design, the methods of testing, evaluation, and benchmarking are loosely delineated [3,6].

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This project was conceived and designed to explore the current state of real-world usability of bedside and central monitoring in a hospital. The aims of this work were to (1) gain insight into whether usability issues exist in hospital monitoring equipment, (2) gather opinions and perceptions about physiological monitoring, (3) explore barriers and successes of current equipment in multidisciplinary practice, and (4) report this unbiased information to the scientific community to improve the user interface design and functionality of physiological displays.

Methods

Design

This was a prospective, descriptive, observational human factors approach to understanding physiologic monitoring usability. This included task analyses, time-motion analyses, and user perception surveys.

Equipment

The equipment used by participants in this study included General Electric (GE) Solar 8000i at the bedside in the intensive care, GE Dash 4000 in the emergency and telemetry units, and GE Central Monitoring Stations. All of the bedside monitors are connected to the central monitoring station in that clinical area. This particular equipment was installed in the intensive care unit in 2007, the telemetry step-down unit in 2010, and the emergency department in 2011.

Data collection

Tasks for analyses were compiled by a group of ECG researchers and experts from the US, UK and Ireland. Each task was considered a basic user function for clinical physiological monitoring, and actual patients being monitored were used. For each task analysis, the participant was asked to rate the perceived difficulty of the task on the 0 to 10 Likert scale [4], with 10 being the easiest and 0 being so difficult that they do not think that they can perform the task. Next, the participant was instructed to select a currently monitored patient, perform the task, and then reset the patient monitoring settings back to the pre-test settings. Times were measured for task performance by 2 raters using digital stopwatches. Also, the numbers of button pushes, screen touches, and mouse clicks were recorded. Monitoring tasks that were included in this project represented seven domains in monitoring functionality (Table 1):

1. Alarms silencing.
2. Alarms and waveform review.
3. Trends display for vital signs.
4. Parameter alarm adjustments.
5. Pacing detection settings.
6. ST-segment monitoring practices.
7. Respiratory rate monitoring (impedance) settings.

Task analysis data collection methods

Alarm silencing. Participants were asked to silence an active monitoring alarm. The alarms may be silenced by either the keyboard button or via the monitor touchscreen, so this was recorded as part of the user interaction. As part of the task analysis, after the alarm was silenced, each participant was asked to turn away from the monitor. Without looking back, the participant was asked to report which patient or what type of alarm was silenced, or both.

Alarms and waveform review. Participants were asked to select a patient and display all of the arrhythmia alarms for the past 24 h with metrics recorded. After closing this patient screen, the participants were presented a scenario where the patient may have changed rhythm in the past hour, and the task was to display the ECG waveform from approximately one-hour ago. The third task in this domain asked the participant to display and print a multi-lead ECG waveform for any of the arrhythmia alarms for the selected patient.

Trends display for vital signs. Participants were asked to select a patient and display a 24-h heart rate trend. The heart rate trend could be from either the ECG or pulse oximetry signals. After the 24-h heart rate trend was displayed, the participant was asked to display a 24-h trend for either blood pressure or pulse oximetry to determine whether intra-task learning was conferred.

Parameter alarms adjustment. Participants were given the scenario of a patient with sinus tachycardia triggering the high heart rate alarm, and they were tasked with adjusting the high heart rate limit upward by 10 beats per minute. Subjects were then asked to adjust the pulse oximetry lower limit to 88%. Since atrial fibrillation often triggers heart rate parameter alarms, adjusting the atrial fibrillation or irregular heart rate setting from an audible alarm to message notification was included in this section.

Pacing detection. Participants were asked to select a patient that they believe to have either a temporary or permanent pacemaker. They were then asked to activate the pacing detection feature for that patient. Subjects were asked to explain what activating the pacing detection feature does to the displayed ECG waveform, and they were asked to describe the differences between the Pace 1 and Pace 2 settings.

ST-segment monitoring practices. Subjects were asked to perform three distinct tasks related to ST-segment monitoring on three different patients. The first task was to change the ST-elevation limit to 3 mm in a single lead. The second task was to change the ST-depression limit to −3 mm in a single lead. The third task was to adjust ST-segment parameters consistent with electrocardiographic monitoring standards in hospitals [5]. Subjects were asked to adjust the ST-elevation and depression settings 1 mm above and below a selected patient's ST-segment baseline. In clinical practice, the ST-segment settings should be tailored in all of the