Maintaining Shared Mental Models in Anesthesia Crisis Care with Nurse Tablet Input and Large-screen Displays

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ABSTRACT
In an effort to reduce medical errors, doctors are beginning to embrace cognitive aids, such as paper-based checklists. We describe the early stage design process of an interactive cognitive aid for crisis care teams. This process included collaboration with anesthesia professors in the school of medicine and observation of medical students practicing in simulated scenarios. Based on these insights, we identify opportunities to employ large-screen displays and coordinated tablets to support team performance. We also propose a system design for interactive cognitive aids intended to encourage a shared mental model amongst crisis care staff.

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INTRODUCTION

Anesthesiologists and other medical doctors operate in crisis care situations, working in high-tempo and time-critical environments that demand both individual and group focus. To improve this focus and direct attention for a given task, doctors sometimes use paper-based checklists to support best practices of care. These checklists are operating documents that serve as cognitive aids, and have been shown to improve quality of medical care by reducing errors [3, 4].

Checklists are new to medical practice, but have been institutionalized in aviation through decades of training and simulation [1]. However, there are important differences between checklist usage in aviation and medicine. In aviation, checklists are used by similarly trained pilots and co-pilots. They are seated in cockpits where controls and displays are co-located. In medicine, a team may include surgeons, anesthesiologists, and nurses—each with their own roles and culture. In an OR, interaction points are spread throughout the environment, from defibrillators to IV lines. Similarly, information sources are distributed widely, from direct patient observation to vitals displays [7].

These differences provide both a challenge and an opportunity for making paper-based medical checklists and cognitive aids electronic and interactive. Crisis care aids in medicine must address these high-tempo, distributed attentional demands, and deal with team-based issues of coordination and communication [2, 5]. A crisis care scenario that exemplifies these demands is the case of pulseless electrical activity (PEA). In PEA, a patient's heart stops beating, causing unconsciousness and can lead to death if treatment is not rapidly and correctly administered. A monitoring anesthesiologist must alternate between looking at a vitals display, a crash cart with drugs to be injected, and other staff members. A second doctor may be performing chest compressions, while a nurse records patient information, and third doctor assists the primary anesthesiologist.

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DESIGN METHODS

After initial meetings with medical professors, we observed six different crisis care simulation scenarios over the course of three months. These scenarios took place as part of different Anesthesia Crisis Resource Management training courses, located at specialized medical simulators at the Palo Alto VA hospital and the Stanford Li-Ka Shing Center. Each simulation run lasted approximately thirty to fifty minutes and involved two resident physician anesthesiologists. Three or four simulation staff acted as surgeons, other doctors, or nurses who played out a pre-planned set of events. A debrief session followed each simulation, involving the cohort of resident physician anesthesiologists, both those who had participated in the scenario as well as those observing remotely, and simulation staff.

Example scenarios included a *Kobayashi Maru*, or unwinnable situation, where the patient cannot be revived, to cases where it was difficult to intubate. In other situations, equipment was configured incorrectly or doctors entered midway into an operation and had to adapt on-the-fly.

Observing from behind a one-way mirror, we made note of: (a) delays or failures in information transfer, and patterns of (b) attention (c) task management and (d) checklist use. For example, we observed one doctor fail to communicate the patient's state as being in V-tach (ventricular tachycardia), since the doctor was talking to someone looking elsewhere. In another case, one participant spoke of always wanting to be "doing" something, and found it hard to step back at times and instead talk about what needed to be done.

During these scenarios, many teams made use of laminated, paper-based cognitive aids. However, we were surprised how little time doctors invested in looking at any particular aid, more commonly spending seconds rather than tens of seconds looking at an aid. We originally imagined that medical checklists could follow the route of interactive checklists in aviation, which sometimes involve item-by-item interaction. However, the extreme time and attentional demands suggested other design approaches.

To begin quantifying these demands, we performed a gaze analysis of a publicly available anesthesia training video (START 2011, episode 6)[1]. Over 4 minutes of acted simulation, we noted 58 actions and speech acts, and tracked one anesthesiologist's gaze as he focused on other staff, the vitals display, the IV lines, crash cart, and the cognitive aid. A single coder recorded 40 gaze sequences, each of which lasted about 6 seconds on average (median 4.5s).

SYSTEM DESIGN

We propose a system design that comprises two main parts: a shared, large-screen display and a tablet controller for input. The large-screen display is mounted on top of a "crash cart," the cart that has the drugs and defibrillator used during PEA. Also mounted on this cart is a flexible arm holding a detachable tablet computer.

Large Display

The gaze analysis and attentional shifting suggested that a large-screen display could provide a large visual target for a team. This screen would display an appropriate crisis checklist, and relevant information such as patient vitals. The display could prompt team conversations both implicitly and explicitly, which would help a team maintain a shared mental model of the crisis. Previous work in aviation has suggested that shared mental models relate positively to team performance [6]. We believe that this same effect will help reduce the incidence of medical errors by helping doctors "stay on the same page"—by sharing a mutual understanding of the current situation as it changes.

Interactive Tablet

Our initial instinct was to give the doctor in charge an interactive cognitive aid to help them manage the crisis and remember key steps. However, our fieldwork and participatory design sessions suggested that it may be currently difficult to get doctors' "buy-in" to interact with an aid. For doctors, the use of an interactive cognitive aid during a crisis can be difficult for both cultural reasons (cognitive aids are not yet widely accepted), and because doctors may not have enough time to control an interactive system. We found an interesting alternative in our design sessions: giving controlling tablets instead to nurses.

Having the nurses drive input through tablets is promising for two reasons. Nursing is very protocol-driven so nurses are used to following checklist-like procedures. Also, nurses in crisis care often function as recorders who write down actions taken and patient vitals over time. Thus, it should be easier to integrate into an existing practice. Furthermore, we will be able to use the information that the nurse records on our large, shared team display.

1http://vimeo.com/19226841

CONCLUSION

The practice of medicine continues to become more complicated and doctors are realizing that they can no longer do everything unaided. While checklists can help, there is great potential in making existing cognitive aids more effective through interactive tools and displays.

We described the early stage design of an interactive cognitive aid. We found that medical crisis care situations provided a challenging design environment for interaction. Initial fieldwork revealed a physically complex information space, and relatively high-tempo time scales of gaze, action, and team-based coordination and communication. These constraints suggested an opportunity to introduce coordinated tablet devices and large screen displays, to help prompt team communication and shared awareness.

We are uniquely positioned to perform fieldwork, test our designs, and evaluate results in a realistic setting: a Medical School's Simulation Center. Insights gained from studying extreme interaction time scales may help designers working in slower-tempo or single-user domains, which still demand split attentions. Lessons learned may also inform the design of information systems in other high-risk, high-tempo fields, where seconds and sound teamwork count.

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