Head-mounted and Multi-surface Displays Support Emergency Medical Teams

Leslie Wu
Stanford University HCI Group
Stanford, CA 94305
lwu2@cs.stanford.edu

Jesse Cirimele
Stanford University HCI Group
Stanford, CA 94305
cirimele@cs.stanford.edu

Jon Bassen
Stanford University HCI Group
Stanford, CA 94305
jbassen@stanford.edu

Kristen Leach
Stanford University HCI Group
Stanford, CA 94305
krleach@stanford.edu

Stuart Card
Stanford University HCI Group
Stanford, CA 94305
scard@cs.stanford.edu

Larry Chu
Anesthesia Informatics & Media Lab
School of Medicine
Stanford, CA 94305
lchu@stanford.edu

Kyle Harrison
Anesthesia Informatics & Media Lab
School of Medicine
Stanford, CA 94305
lchu@stanford.edu

Scott Klemmer
Stanford University HCI Group
Stanford, CA 94305
srk@cs.stanford.edu

CSCW '13 Companion, Feb. 23–27, 2013, San Antonio, Texas, USA.
ACM 978-1-4503-1332-2/13/02.

Abstract
Emergency medical teams collaborate to solve problems and take care of patients under time pressure and high cognitive load, in noisy and complex environments. This paper presents preliminary work in the design and evaluation of head-mounted and multi-surface displays in supporting teams with interactive checklists and more generally dynamic cognitive aids.

Author Keywords
Large displays; Medical interfaces; Checklists; HMD; HUD

ACM Classification Keywords
H.5.m. H5.2 [Information interfaces and presentation]: User Interfaces. - Graphical user interfaces

General Terms
Design; Experimentation; Human Factors

Introduction
Emergency medical care is an example of a paced, stressful, team-based task domain that involves volatile, uncertain, complex, and ambiguous tasks.

Emergency Medical Teams

Unlike traditional office work, crisis medical teams work in highly co-located, paced, emergency environments with high demands on cognition and communication [11]. Operating rooms and hospital wings can be very information dense, and medical code teams may involve over a dozen people responding over a short period of time. This provides a challenge for the design of interactive information technologies that attempt to support medical doctors, nurses, technicians and emergency staff as they respond quickly to unexpected situations.

Figure 1 – Crisis Simulator. Photo by Stanford EdTech

Interactive Cognitive Aids

Whereas checklist usage has been commonplace in high-risk fields such as aviation and nuclear power for decades, they are now only becoming standard practice in medical care [5]. They have been shown to be effective in supporting everyday procedures such as putting in central lines to improving crisis response in trained medical teams [6].

Information technology provides the opportunity to develop interactive and dynamic cognitive aids [11,12] (such as checklists) to support medical practitioners adhere to best practices and thereby mitigate the risk of medical errors and adverse events.

Benefits

Cognitive aids can serve not only as memory aids (reminding doctors to dose certain drugs such as epinephrine at a certain periodicity, or setting the joules on a defibrillator correctly), but attentional aids. In a crisis environment, tunnel vision may lead doctors to stick with one initial diagnosis rather than considering alternate competing hypotheses [4].

Interactive aids can also facilitate information access—being able to quickly pull up relevant checklists and protocols, as well as provide patient information. This patient information may include patient records, as well as recently run lab results (such as arterial blood gas). During time-critical procedures such as Advanced Cardiac Life Support (ACLS), interactive aids could provide cueing for improved CPR ("compress faster") and ventilation rates.

Barriers to Use

Medical teams contain members trained in varying disciplines, each with their own culture and norms. Medical training also emphasizes knowledge retention and educational practices focus on fast but rote recall of diagnoses and procedures [5].

In contrast, cognitive aids and technologies designed to support medical teams do not assume that doctors remember everything—instead they encourage protocol-driven operation, which medical professionals

Principles of Interactive Cognitive Aids

Reduce barriers to Use: Understand and fit into existing work practices by building information displays that support medical doctors during routine care. Then allow these to be transitioned to crisis mode.

Cue based on Context: Be selective in what information is displayed and when—use sensors if possible to detect context, or rely on nurse input to frame the situation. Use this context to specialize information display and guide doctors to appropriate aids.

Reduce complexity: Doctors have limited attention windows for cognition and communication. Reduce the information complexity by showing only a subset of the protocol—what doctors need to know now. Reduce input complexity by offloading tasks to nurses and other operators.

may resist. Finally, medical culture must deal with the intersection between information artifacts and social hierarchy. How might device use and protocol changes affect and be influenced by social norms between surgeons, doctors, and nurses?

Design: Multi-surface Displays

As part of the design process, the computer scientists on the team spent over a year observing dozens of medical simulations held in a high-fidelity, mannequin-based simulation environment [4]. In these simulations, anesthesiologist residents responded to crisis situations as observers watched from behind a one-way mirror. These scripts included performances by confederate actors played by medical doctors, and were videotaped from multiple angles. After each simulation, doctors participated in a short debrief period where they watched themselves react and discussed principles of crisis resource management [4].

This design process revealed the attentional demands during crisis [11] and lead to the development of large-screen and tablet based software systems which were deployed to anesthesiologists in several scripted crisis simulations [11, 12].

Shared Mental Models

Interviews with medical doctors also revealed the importance of maintaining a shared mental model. Thus, designs incorporated a large-screen display to support team awareness to make sure everyone was on the same page as to the state of the crisis [6] and how it was to be treated. In future work we hope to evaluate how these displays may support team awareness.

Head-mounted Displays

Evaluation of interactive cognitive aids suggested that large-screen and tablet displays may be able to support doctors in crisis response [11]. However, this revealed the attentional timeframes involved—on the order of seconds rather than minutes. Doctors had to split attention between vitals displays, cognitive aids, crash carts, other doctors, the patient and peripheral artifacts such as drug vials and other monitors. Given this, some work has investigated the role of head-mounted displays in reducing attentional shifts. However as cognitive aid use increases, head-mounted displays may also support effective cueing and aid use.

Smartphones

Smartphones have been replacing pagers at a small, but growing number of hospitals [2]. They have been used to access patient records, as on-hand procedural references, and (of course) as ordinary mobile phones. However, little exploration has been carried out in the specific domain of informing physicians on their way to medical crises.

Upon arrival, these doctors will need to quickly figure out what patient statistics and treatments have been administered, as well as obtain any relevant patient history. This information is usually doled out from the highest ranking caregiver currently at the scene, and is delivered as a fast-paced 'shotgun blast' of information. It would seem that a physician's hurried journey to a medical crisis might provide a window of opportunity to prime them for this information transfer, through their smartphones, so that they might arrive at a more complete shared mental model of the crisis with the other care providers and be better equipped to determine the underlying causes behind the symptoms.

Figure 2 - A screenshot of an interactive cognitive aid for ventricular tachycardia. On the left: protocol-specific information on drug timing and dosages. On the right: people in the room with names and roles; patient information

Input Mechanisms

The interactive cognitive aid systems we have designed (see Figure 2) give primary input and control to a nurse that operates the system, leaving doctors to give voice commands as they normally do.

Related work

Researchers have investigated the spatial dimensions of hospital collaboration [1] as well as various aspects of trauma care [8, 9]. Checklists have been well studied in aviation [3] and have been evaluated in medical simulation [6, 13] and practice [5].

Acknowledgements

Thanks to POMI and the Stanford DARE graduate fellowship for supporting this research.

References

[1] Bardram, J.E. and Bossen, C. Mobility Work: The Spatial Dimension of Collaboration at a Hospital. Computer Supported Cooperative Work (CSCW) 14, 2 (2005), 131–160.

[2] Burdette J., Herchline S., Oehler T. Practicing medicine in a technological age: using Smartphones in clinical practice. Clinical Infectious Disease 2008;47: 1 17-22.

[3] Degani, A. and Wiener, E. Human factors of flight-deck checklists: The normal checklist. 1990.

[4] Gaba, D.M., Fish, K.J., and Howard, S.K. Crisis Management in Anesthesiology. Churchill Livingstone, New York, 1994.

[5] Gawande, A. The Checklist Manifesto: How to Get Things Right. Metropolitan Books, 2009.

[6] Harrison, T.K., Manser, T., Howard, S.K., and Gaba, D.M. Use of cognitive aids in a simulated anesthetic cri- sis. Anesthesia and analgesia 103, 3 (2006), 551–6.

[7] Haynes, A.B., Weiser, T.G., Berry, W.R., et al. A surgical safety checklist to reduce morbidity and mortality in a global population. The New England journal of medicine 360, 5 (2009), 491–9.

[8] Sarcevic, A., Marsic, I., and Burd, R.S. Does size and location of the vital signs monitor matter? A study of two trauma centers. Annual Symposium proceedings / AMIA Symposium. AMIA Symposium, (2010), 707–11.

[9] Sarcevic, A., Palen, L.A., and Burd, R.S. Coordinating time-critical work with role-tagging. Proceedings of the ACM 2011 conference on Computer Supported Cooperative Work - CSCW '11, ACM Press (2011), 465.

[10] Winters, B.D., Gurses, A.P., Lehmann, H., Sexton, J.B., Rampersad, C.J., and Pronovost, P.J. Clinical review: checklists - translating evidence into practice. Critical care (London, England) 13, 6 (2009), 210.

[11] Wu, L., Cirimele J., Card S., Klemmer S., Chu L., Harrison K. Maintaining Shared Mental Models in Anesthesia Crisis Care with Nurse Tablet Input and Large-screen Displays. Poster at UIST: ACM Symposium on User Interface Software and Technology. October, 2011.

[12] Wu, Leslie. Medical Operating Documents: Dynamic Checklists Support Crisis Attention. Doctoral Symposium & Poster at UIST: ACM Symposium on User Interface Software and Technology. October, 2012.

[13] Ziewacz, J.E., Arriaga, A.F., Bader, A.M., et al. Crisis checklists for the operating room: development and pilot testing. Journal of the American College of Surgeons 213, 2 (2011), 212–217.e10.