Quantifying Adaptation Parameters for Information Support of Trauma Teams

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CHI 2008, April 5 – April 10, 2008, Florence, Italy
ACM 978-1-60558-012-8/08/04.

Abstract
Trauma centers are stressful, noisy and dynamic environments, with many people performing complex tasks, and with little in the way of information support. Information must be prioritized and filtered to avoid overload or loss. This work quantifies the information-selection parameters that will guide adaptive user interfaces for trauma teams.

Keywords
Healthcare, teamwork, cognitive work analysis, adaptive interfaces, decision support

ACM Classification Keywords
H.5.3 Group and Organization Interfaces—Computer-supported cooperative work; H.1.2 User/Machine Systems—Human information processing.

Introduction
Modern society increasingly depends on the work of teams of skilled individuals that use complex communications and processes to achieve their goals. Our work focuses on advanced trauma care, an example of such a domain. During trauma resuscitation, potentially life-threatening injuries are rapidly identified and treated, and plans for hospitalization are developed (Figure 1). While every

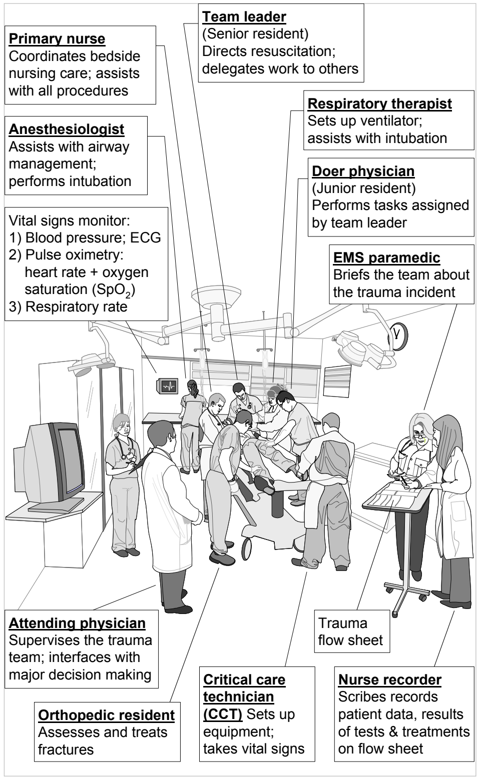

Figure 1: Emergency department (ED or ER) trauma bay: typical actors and artifacts in a trauma resuscitation event.

patient and their injuries are unique, there are principles underlying the care of injured patients that are known to improve care and efficiency [1].

Despite process standardization and highly trained personnel, human errors and inefficiencies are still observed during resuscitations [3]. Errors disrupt the flow of care, slow the speed and efficiency of the evaluation and may have cascading effects leading to poor patient outcome. To reduce the number of errors and improve efficiency in trauma teamwork, we need to understand not only how teams work and exchange information, but also how to automatically capture team communication, evaluation, and management processes in real time. Real-time error management will require the development of monitoring technology that can detect communication and process failures and provide critical information effectively.

Our long-term goal is to develop a "smart resuscitation room" that can automatically capture trauma team activities for offline and online analysis of teamwork. If we can deliver information as it is needed, we can reduce the number of repeated inquiries, the delays waiting for data and scan results, and the probability of an error caused by the lack of information. All of these improvements offer the possibility of reducing the cost of trauma care and increasing its quality.

To date, it is not known whether computer aids for trauma resuscitation should support certain individuals, the overall team, or both [2]. The team's activities and information needs hinge on a continuous flow of information about patient status from many sources inside and outside the hospital. The team must continually incorporate and adapt to information without losing focus on the patient. These conflicting demands mandate *prioritization and filtering of information streams*. The main challenge to the application of information technologies in this setting is developing a system to *dynamically adapt the user interface* based on "intelligent" selection from the universe of relevant information in this domain. To present information selectively based on changing information needs of collaborative teams, the following questions need to be answered:

a) "what" type of information to present (e.g., vital signs, medications given, medical history)
b) "when" to present specific information during the evaluation process
c) "who" is the current target of information presentation, i.e., specific team member(s), or role(s), or the entire team
d) "where" to present information (modality of presentation and the spatial location of the device on which the information is presented), and
e) "how" to present needed information (e.g., color vs. monochrome, text vs. graphics).

Most previous research in human-computer interaction (HCI) and computer-supported collaborative work (CSCW) has focused on the "where" and "how" of information presentation, e.g., [7][8]. While these are important aspects, this research does not deal with *who* needs to know, *what*, and *when*, which represent the first step in designing information presentation systems for time-critical settings such as trauma care.

Preliminary studies and results

We did a pilot study to determine the trauma team's dynamically changing information needs and answer the "who," "what," and "when." The answers to these questions depend on factors such as team's current tasks, team structure, information needs of individual members, patient status, and types of occurring errors or inefficiencies. To quantify these factors, we have recorded trauma events using two ceiling-mounted cameras and microphones. In the past year, we have observed 10 events, including 8 actual resuscitations and 2 performed on a robotic patient simulator at a Level 1 (highest) trauma center. Consent for recording was obtained in advance from all potential participants. To maintain confidentiality, recordings were transcribed within 96 hours and then erased. Transcripts were produced by a member of the research team who is an expert in work analysis methods and trained to recognize work flow during trauma resuscitation. A domain expert (trauma surgeon) verified the accuracy of each transcript. The coincident occurrence of tasks and communication required several views of the event and repeated review of the recordings for transcription. About 20 hours were needed to transcribe and tag a 20-minute video. Each event typically included >400 discrete tasks or communications, showing the complexity of this work domain.

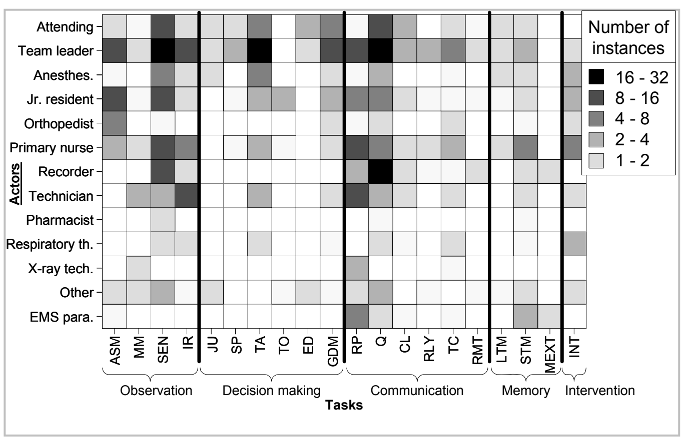

Figure 2: Average frequency of task performance.

Transcription is based on the *parallel columnar transcription scheme*, which is commonly used in interaction analysis [4]. Each discernable action of each team member is transcribed in a separate row. Each line includes the kind of action or utterance (diagnosis, treatment, inquiry, report, etc.) and identifies who did or said something based on their role: physician, nurse, technician, etc. The object or target of the action is also included along with a textual description of what was said or done.

After the transcription is completed, each row is assigned one or more semantic codes. The codes belong to two coding schemes: (1) medical task codes, which represent the medical goals of the actions and provide the semantic context (e.g., oxygen administration, blood transfusion); (2) control task codes, which represent the behavioral aspects of the actions, such as *observation* (e.g., physical assessment, instrument reading), *decision-making* (e.g., strategic planning, task assignment), *communication* (e.g., report, inquiry, clarification), or *intervention* [6]. Every activity observed in a videotaped resuscitation is assigned both medical- and task codes. The details of our coding schemes and several coded transcripts are available at: http://www.caip.rutgers.edu/tru-it/download/

<u>*Analysis of the task-role relationship*</u>: Individual tasks are strongly associated with worker roles even with variations in teams and resuscitation scenarios. To graphically depict their work, we averaged the frequency of task performance over different trauma teams confronted with two actual and two simulated resuscitations (Figure 2). We were surprised to observe that the averaged matrix did not tend to become uniformly gray. It instead retained the dark peaks and empty regions. This constancy of the role-to-task relationship suggests that variations in the distribution of tasks across teams and resuscitations are minor despite the need for adaptation to different scenarios. For example, simple observation tasks, such as instrument reading (IR) and manual measuring (MM)

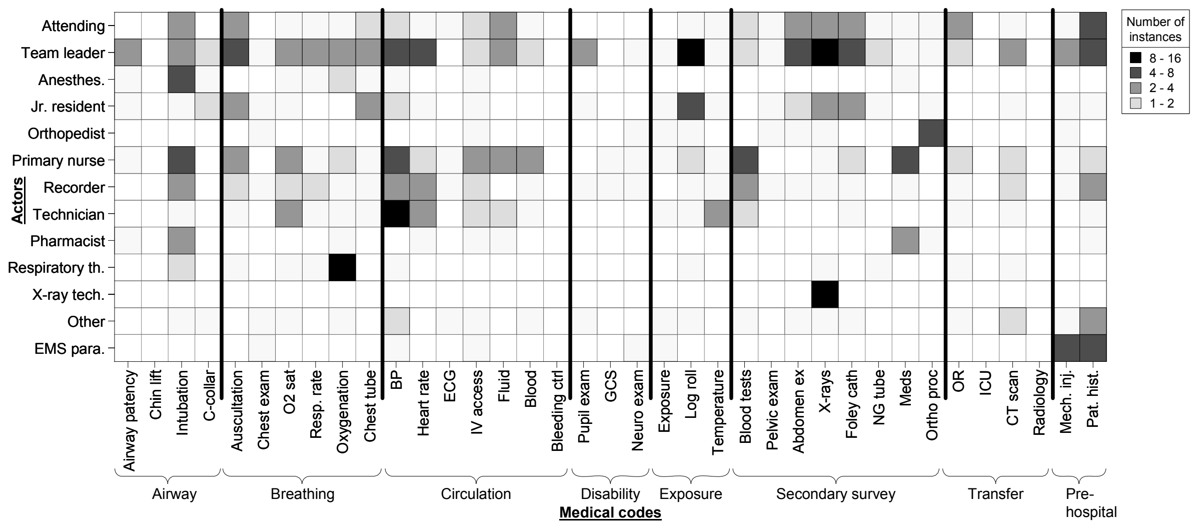

Figure 3: Frequency of medical task performance averaged over four actual and two simulated resuscitations.

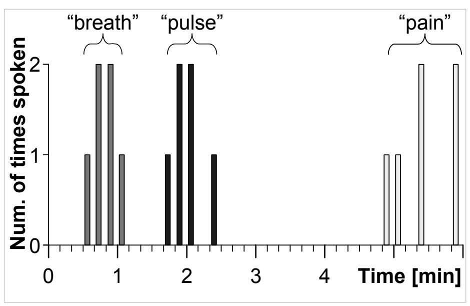

Figure 4: Keyword tracking over time.

were done mostly by technicians and nurses, while more complex observations, such as sensing and assessment (SEN, ASM) were done by team leaders, attending physicians and residents. The decision making tasks were mainly done by team leaders and attending physicians. Although there is no specific training for communication- and memory-lookup related tasks in the trauma protocol (unlike observing, deciding, and intervening), these tasks also exhibit constancy across roles and events. Most of the inquiries (Q) were by recorders, team leaders, and attending physicians, while most reporting (RP) was by technicians. Team members rarely obtain information from artifacts such as trauma flowsheet or EMS report notes (MEXT) and typically only one member did this.

Similar constancy is observed for medical tasks (Figure 3). For example, airway tasks were mostly performed by the anesthesiologist and primary nurses, breathing tasks by the team leaders and respiratory technicians, and circulation tasks by the primary care technicians, primary nurses and team leaders. *The quantitative results presented in Figures 2 and 3 provide the basis for answering "who" in the team needs "what" kind of information and "when" during patient evaluation*.

<u>*Analysis of information needs*</u>: Trauma teams manage large amounts of information about patient status and their current activities over the course of a resuscitation event. This information becomes available in a short time period (<20-30 minutes) and in a continuous data flow from sources both inside and outside the hospital. Our pilot analysis of inquiries posed by team members during four trauma resuscitations revealed over 60 different types of information needed in a typical event [5]. The most frequent types of information needed were patient demographics and medical history, details about the mechanism of injury, vital signs, status of major physiological systems such as airway, breathing, and circulation, and details about the equipment and instruments used. Not all of this information is equally complex nor it is needed at all times. For example, patient vital signs are needed throughout the resuscitation; details about the injury event are typically sought when making important decisions about tests or treatments; different physiological assessments are mentioned mostly during different stages of the trauma-care protocol [1].

The time-varying character of team's information needs can also be observed by tracking words and phrases uttered by team members during the resuscitation process. As an example, the keyword "breath" was spoken several times at the start of the resuscitation

Information display mode	**WHAT** information is displayed	**WHEN** displayed	**WHERE** displayed	**HOW** information is displayed
By default	Chosen at design time, based on ethnographic studies.			Chosen at design time, based on interface studies.
On demand	Chosen at runtime, on user request.		Chosen at design time.	
In anticipation	Answered at runtime, based on context monitoring, expert rules and statistical models.			

Table 1: How aspects of information presentation for trauma teams will be answered.

(Figure 4). In the second minute, the word "pulse" was spoken six times (and then not again). About five minutes into the process, the word "pain" was spoken several times. This order shows that the team is conforming to the protocol [1]: first checking the airway and breathing, then circulation, and lastly looking for other problems after the basic steps have been covered. *By categorizing the types of words and phrases that are used as well as their intended recipients, we can understand what information has to be delivered to whom*.

In our initial studies we have observed several instances in which difficulties arose with managing critical information, leading to information overload or mismanagement. Examples include: (a) overlapping inquires and reports, i.e., when several team members simultaneously ask for or report different types of critical information; (b) frequently repeated inquires or reports, i.e., when different types of critical information are asked for or reported in short intervals (e.g., every minute); and, (c) complex information that is being asked for or reported, i.e., some types of information are more complex than others (e.g., physiological status vs. patient name).

Our preliminary analysis of questions asked during resuscitations also helps uncover the information needs of each team member and how these vary. Analyzing inquiries alone, however, does not reveal all the information needs of trauma teams. We are currently analyzing actions (e.g., what team members look at or do) and interviewing different team members about their information needs.

Preliminary design implications

Our quantitative and qualitative analyses of recorded resuscitations will allow us to specify the dynamically-changing information needs of trauma teams. Based on the above results, we believe that three modes for presenting information will be needed (see Table 1):

- *By default*: basic information that must be displayed unconditionally all the time for all team members or targeted to specific team members.

- *On demand*: information requested interactively by team members (directly, via spoken commands, or indirectly, by asking the recorder nurse). An additional requirement for the on-demand mode is an interactive user interface that allows for quick navigation and information access.

- *In anticipation*: information that is dynamically selected, by automatic monitoring of patient and teamwork/process information, to respond to anticipated needs. This component requires design of expert rules and statistical models for context-driven information presentation.

Our long-range goal is to develop a "smart room" that will automatically monitor the trauma process in real time. This system will capture several features including the stage of the resuscitation, team members' roles, tasks, and locations, patient's vital signs, team structure, and workload. Based on the real-time monitoring, expert rules and probabilistic models will infer individual- and team information needs and perform information prioritization and filtering.

Based on the transcripts, we can deduce which information is most likely to be requested at each point of the procedure. We can then plan displays that will help deliver that information to the team. These may either be based on expert rules or on statistical predictions. As an example of a rule, we know that after initial airway and breathing checks, according to the trauma-care protocol [1] the blood pressure and pulse rate are the next critical pieces of information. As an example of a probabilistic model, we might use Bayesian analysis to determine which behaviors during the resuscitation are most likely to result in a request for the blood pressure. We plan to develop models to judge how often we can anticipate information requests and provide the information from automatic instruments or signal the nurse recorder to display this information.

Conclusions

This paper describes our preliminary findings about teamwork information behavior for emergency trauma teams. The contribution of this work to HCI field is a technique for quantifying dynamically-changing information needs of teams in high-risk domains. We have introduced a novel task coding scheme and evaluated it on several resuscitation events. This representation allowed us to quantify task-role relationships and information needs in trauma teams. Based on our initial data analysis, we have determined preliminary answers to design issues related to "what" information is needed, "when" during patient evaluation it is needed, and for "whom" it should be displayed. We are continuing the recording and data analysis. Our main future effort is to continue deriving accurate statistical models and identifying the expert rules needed for selection of critical information. These studies will allow us to more effectively design interfaces for presenting the chosen information to answer "where" and "how."

Acknowledgements

We thank J. Hammond, M. Tinti, M. Markus-Rodden, J. Wilder and ED staff at Robert Wood Johnson Hospital.

References

[1] American College of Surgeons, Advanced Trauma Life Support® (ATLS®), 7th Edition, Chicago, IL, 2005.

[2] Gertner, A. S., and Webber, B. L. TraumaTIQ: Online decision support for trauma management. *IEEE Intelligent Systems, 13, 1*, 32-39, 1998.

[3] Gruen, R. L., et al. Patterns of errors contributing to trauma mortality: Lessons learned from 2594 deaths. *Annals of Surgery, 244, 3*, 371-380, 2006.

[4] Jordan, B., and Henderson, A. Interaction analysis: Foundations and practice. *The Journal of Learning Sciences, 4, 1*, 39-103, 1995.

[5] Sarcevic, A. Human-information interaction in time-critical settings: Information needs and use in the emergency room. *ASIS&T'07 Annual Meeting*, Milwaukee, WI, Oct. 2007.

[6] Vicente, K. J. *Cognitive Work Analysis: Toward Safe, Productive, and Healthy Computer-Based Work*. Mahwah, NJ: Lawrence Erlbaum Associates, 1999.

[7] Wigdor, D., Shen, C., Forlines, C., and Balakrishnan, R. Effects of display position and control space orientation on user preference and performance. *CHI '06*, 309-318, Montreal, Canada, April 2006.

[8] Xiao, Y., Lasome, C., Moss, J., Mackenzie, C.F., and Faraj, S. Cognitive properties of a whiteboard: A case study in a trauma centre. *ECSCW '01*, 259-278, 2001.