Chapter 12

Team Performance under Stress

In this chapter, we wish to report the results of video analysis of team coordination during stressful situations. We attempt to answer the following two questions: (1) What strategies were used by practitioners to achieve coordinated activities? (2) What was the nature of the situations in which coordination breakdowns were observed? The answer to the first question can provide us with information, for example, on how to design workplaces and interfaces to facilitate team coordination (*e.g.*, Segal, 1994). The answer to the second question can direct us at those challenging situations where team coordination is crucial and is prone to breakdowns, and thus one can target team training accordingly.

It should be reiterated here that the domain of patient resuscitation is a dynamic, complex, and high-risk one, and the teams in this domain often have to function under extreme time pressure and with considerable amount of uncertainty. Thus this environment can be used as a research vehicle to study team performance in stressful and complex task domains that are similar to but not limited to medical domains.

12.1 Task Complexity and Team Coordination

12.1.1 Introduction

Collecting and examining human performance data and cataloging human errors are certainly important in improving the quality of care in emergency medicine. An orthogonal approach is to understand potential mismatches between capacities of individuals and teams and demands of tasks presented to the care givers. One way of predicting task demands is through the investigation of task complexity, a characterization of tasks that describes why tasks are complex to perform. As evidenced by Woods' (1988) treatment of the topic of task complexity, many valuable insights can be obtained by examining the nature of task complexity from the viewpoint of its impact on activities. From previous incident reports, simulator investigations and field studies, Woods synthesized a picture of cognitive demands due to task complexity and plausible ways in which individuals cope with task complexity, particularly during crisis situations. Such a picture can help us in predicting what types of cognitive problems are likely to confront practitioners, and what types of cognitive support are likely to be useful.

Various definitions of the concept of task complexity have been put forward, mostly in the context of well-defined experimental tasks. Three such definitions are described here as examples. For a multiple choice task, Payne (1976) used the number of alternatives as a measure of task complexity. For an inspection task, Gailway and Drury (1986) used the number of different fault types as a measure of task complexity. For a monitoring task, Kennedy and Coulter (1975) used the number of channels to be monitored as a measure of task complexity.

Real life tasks in most situations are a combination of these and other individual tasks, and thus the definition of task complexity is not clear cut. One attempt was by Woods (1988). He proposed a four dimension scheme oriented for tasks in process control environments to define task complexity: dynamic situations, interacting parts, uncertain data, and risk. These dimensions were proposed for the prediction of demands for cognitive activities and not for the prediction of demands for team coordination.

Despite the fact that most tasks in workplaces are handled by a group of people working as a team, little empirical or theoretical work has been reported to characterize task complexity for a team environment. No framework has been put forward to understand what makes coordination of a task complex for a team.

As a first step toward delineating the components of task complexity when team performance is concerned, a study was conducted to contrast the characteristics of one emergency medical procedure observed under two types of circumstances differentiated by task urgency. After the description of the method and results of the study, four components of task complexity are identified that explain *in what ways* the tasks in emergency situations are complex for teams to perform. Based on the findings of the study and the components of task complexity proposed, the implications of task complexity for team coordination are discussed.

12.1.2 Extraction of Data for Studying Task Complexity

Based on a task analysis of tracheal intubation, a review form was designed to extract the following information from review of the videotapes of patient care.

(1) The patient's status upon arrival, e.g. in hemorrhagic shock or unconsciousness.
(2) Technical difficulty of intubation: subjective ratings of intubation difficulty, number of attempts before successful intubation, airway suctioning activities, and time of connecting the ET tube to a mechanical ventilator.
(3) Patient physiological monitoring information available during the course of intubation.
(4) Pace of work: the tasks accomplished before intubation (out of 15 in total) and duration of intubation.

The form included 29 items of multiple-choice questions, checklists, and timings of specific events for intubation. Anesthesia care providers experienced in tracheal intubation were asked to review the videotaped intubation and fill the review form. Interrater reliability was assessed by intraclass correlation coefficient (Shrout & Fleiss, 1979).

12.1.3 Analysis

The cases were divided into two categories according to how urgently intubation was needed: *high-urgency intubation*, performed within 10 minutes of the patient's admission, and *low-urgency intubation*, performed 10 minutes after the patient's admission. This division was used to contrast tasks with different levels of time pressure exerted on the care givers. Unidirectional χ^2 tests were used for comparing frequencies of occurrence and proportions of the tasks accomplished, and t-tests were used for comparing time durations.

12.2 Results

Over 100 cases were recorded during the period of 3 years, 48 of which showed intubation performed by 21 different anesthesia care providers. Among the 48 intubation procedures, 17 (35%) were high-urgency intubation. These all occurred in the patient admitting areas. Among the low-urgency intubation procedures, 15 occurred in the admitting areas, and 16 in the operating rooms. A total of 11 different videotape reviewers were used. The average number of reviewers for each case was 2.7. Intraclass correlation coefficients ranged from moderate (.57 for the question of "intubation rated as very difficult") to excellent (.99 for the question about the timing of events).

Figures 12.1 and 12.2 summarize the results of comparison of patient status upon arrival, available monitoring information, technical difficulties, and pace of work between the two types of intubation procedures. All comparisons were statistically significant at $p < 0.05$.

The patients requiring high-urgency intubation were significantly more likely to be in hemorrhagic shock (33% versus 0%), and they were more likely to be unconscious (69% versus 7%) than were those requiring low-urgency intubation. The amount of patient monitoring information available was significantly less during high-urgency intubation than during low-urgency intubation, shown by the availability of four important sources of monitoring information (Figure 12.2). Tasks were technically more difficult in high-urgency intubation, as reflected in four of the comparisons in Figure 12.1: (a) high-urgency intubation was more likely to be rated as "very difficult" than was low-urgency intubation (33% versus 7%); (b) high-urgency intubation was more likely to require multiple attempts before success (41% versus 20%); (c) Airway suctioning was more likely to occur in high-urgency intubation (56% versus 17%); and (d) High-urgency intubation took longer than in low-urgency intubation for the anesthesia care providers to connect the ET tube to the mechanical ventilator (44% versus 94% connected within 4 minutes). The duration of high-urgency intubation was significantly shorter than that of low-urgency intubation (252 seconds versus 420 seconds). More tasks were omitted in carrying out high-urgency intubation than low-urgency intubation (26% versus 14%).

12.3 Components of Task Complexity

The findings from the study suggest that when carrying out high urgency tasks, the anesthesia care providers had to take care of patients whose condition was more critical

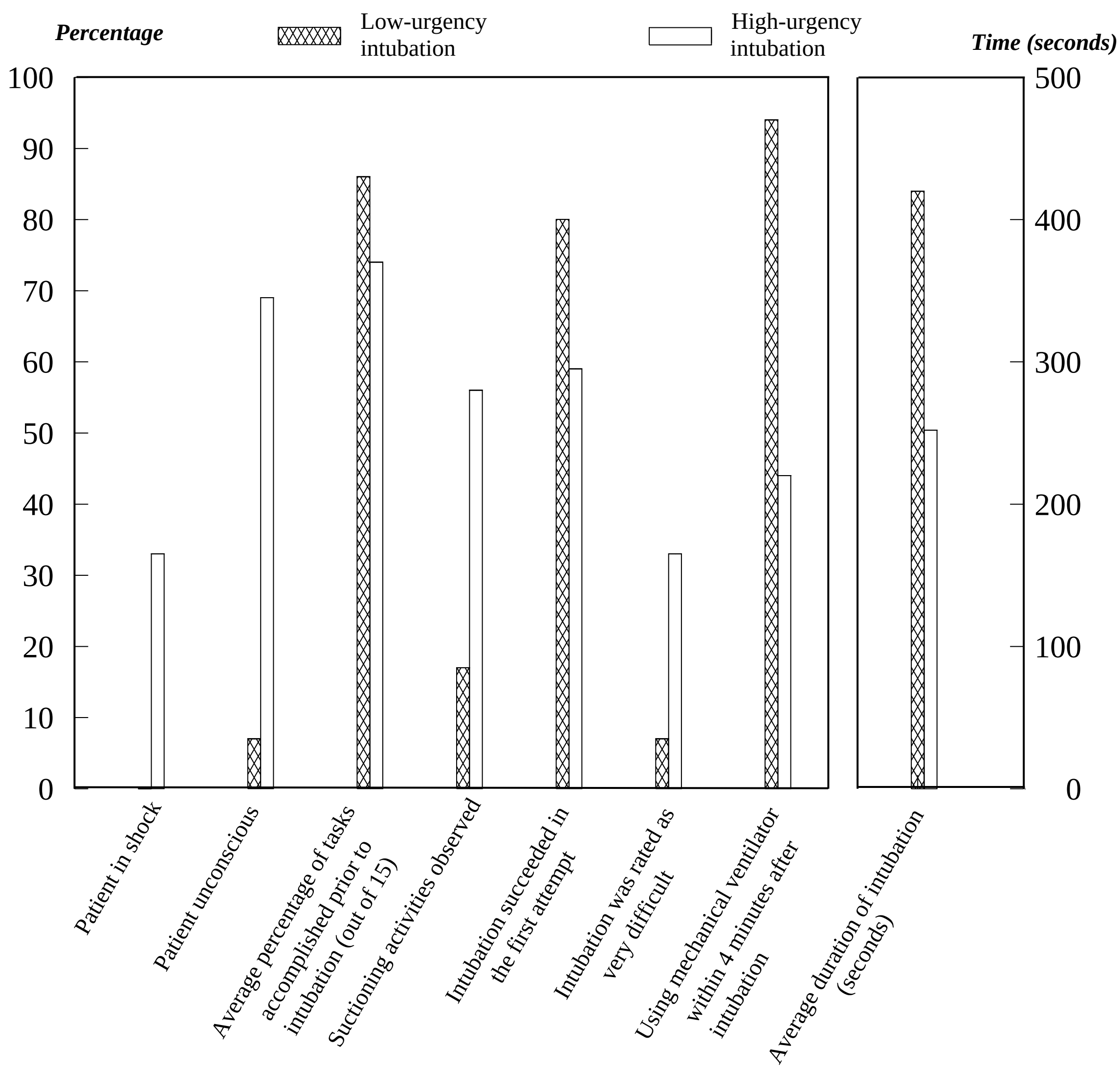

Figure 12.1: Comparison of two types of intubation: high versus low urgency. Unidirectional t-test was used for duration comparison, and χ^2-test for proportion and frequency comparison. All comparisons listed here are statistically significant at $p < 0.05$.

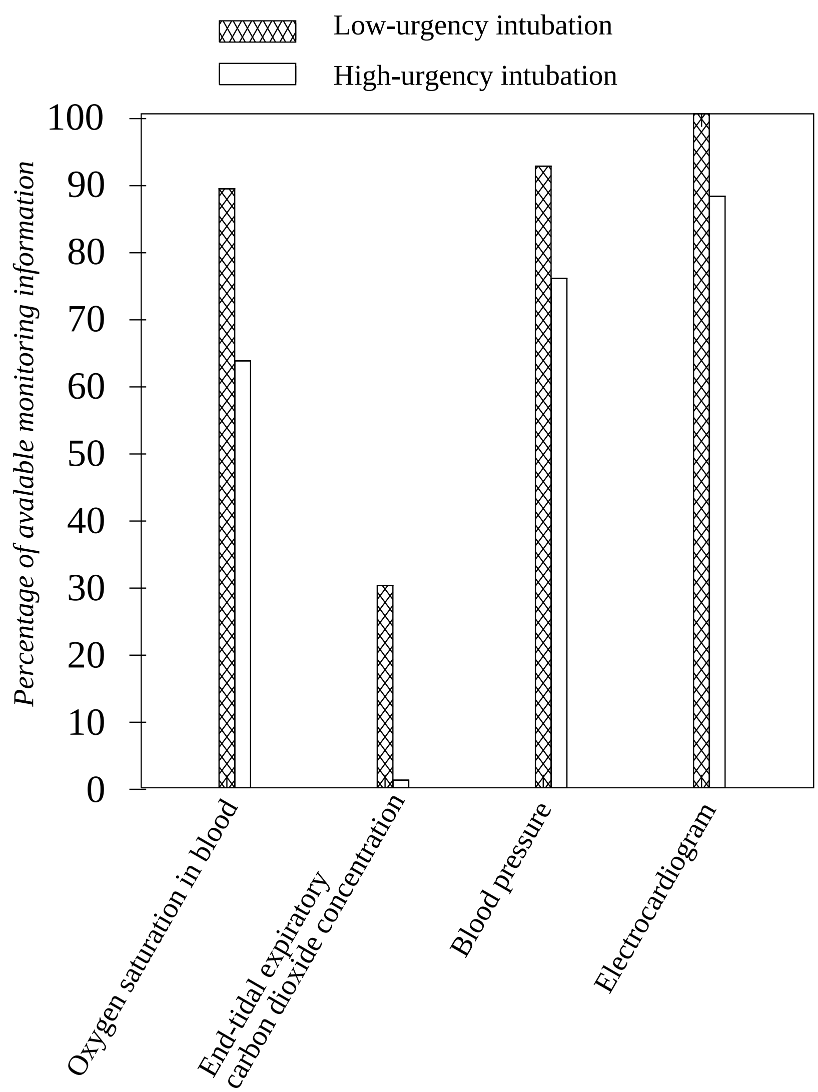

Figure 12.2: Monitoring information available during low and high urgency intubation. χ^2-test was used to compare the frequencies listed here. All comparisons were significant at $p < 0.05$.

with less monitoring information available, and they accomplished tasks that were more difficult at a faster pace.

Based on the comparison of the task characteristics of low- and high-urgency intubation, four components of the task complexity facing emergency medical teams can be identified: (1) multiple, concurrent tasks, (2) uncertainty, (3) changing plans, and (4) compressed work procedures and high workload.

Multiple, Concurrent Tasks

As one would expect and shown by the data presented here, patients were more likely to be in hemorrhagic shock when they required high-urgency intubation. For a patient in hemorrhagic shock, achieving intubation was only one of the immediate resuscitation objectives. Other equally important objectives were simultaneously required, such as normalization of vital signs and restoration of adequate blood circulation. Therefore while the anesthesia care providers were carrying out intubation, other members (*e.g.*, the surgeon) of the resuscitation team would concurrently complete other essential tasks.

Uncertainty

During high-urgency intubation desirable monitoring information was often unavailable even though it was routinely available during low-urgency intubation (Figure 12.2), although the same monitors were available regardless of task urgency. Several factors contributed to the decreased use of patient monitoring information during high-urgency intubation. One factor was that often there was simply not enough time for the care givers to set up the desired monitors. This was suggested by the finding that more tasks, some of which were monitor setups, were omitted in high-urgency intubation than in low-urgency intubation. The second factor was that even when the team attempted to set monitors up, many patients were uncooperative and even combative (due to impairment of consciousness which was more frequent in the patients requiring high-urgency intubation; see Figure 12.1). This non-cooperation led to difficulties in placing and in maintaining patient sensors in the correct position needed for successful monitoring. A third reason was that the condition of some patients was so unstable (i.e. in cardiac arrest) that some of the monitoring information could not be obtained reliably.

The amount of information obtained through direct, clinical assessment was also often reduced in high-urgency intubation. Due to the high percentage of unconscious patients in high-urgency intubation, it was often difficult for the resuscitation team to collect critical information about the patient, such as medication, past medical history and mechanisms of injury. Another indication of reduced clinical information was the obstructed view during airway management indicated by increased occurrences of suctioning activities needed because of the presence of secretions or blood. (refer to the task description above).

Changing Plans

The findings of this study indicate that tasks were more likely to require multiple attempts and were more difficult when task urgency was high. These aspects of task characteristics suggest that emergency care givers often had to consider and switch to alternative plans. For example, when intubation was very difficult, anesthesia care providers had to consider alternative, contingency plans to ensure adequate ventilation (such as establishing a surgical airway through the neck).

Compressed Work Procedures and High Workload

The finding that the duration of high-urgency intubation average only about half as much as that of low-urgency intubation (Figure 12.1) indicates hastened work procedures. In addition, extra steps often had to be performed in emergency situations. Such extra steps were suggested by three of the findings of the study.

First an increased need for suctioning was found in high-urgency intubation. Suctioning of the patient's airway slows down the intubation process and adds to the workload of the anesthesia care providers. Second, the use of a mechanical ventilator after high-urgency intubation was delayed when compared to low-urgency intubation. Manual ventilation occupied the much needed attention that could be available for other essential tasks if a mechanical ventilator is used. One explanation for the delayed use of a mechanical ventilator is that the integrity of the patient's lungs is usually closely evaluated by manually ventilating the patient. This is necessary because chest X-rays and other evaluations may be incomplete during the early stage of resuscitation when intubation was urgently needed. Another factor is that high-urgency intubation is often performed when multiple personnel are around the patient performing other tasks, which makes it difficult for anesthesia care providers to connect the ventilator. Thirdly, the study found an increased proportion of unconscious patients among those requiring high-urgency intubation. Extra steps are often necessary in caring for unconscious, semi-conscious, or combative patients as it is difficult for the resuscitation personnel to get cooperation from the patient.

12.4 Implications for Task Complexity in Team Environments

As pointed out by Hackman and Morris (1975), the performance of a team depends on the ability of a team to coordinate its members' capabilities and efforts. Special skills and efforts are needed to synchronize individual members' activities. Fleishman and Zaccaro (1992) summarize such needs in a taxonomy of team functions, which include monitoring of each others' activities and distribution of task workload.

A number of strategies are available for emergency medical care personnel to coordinate and to fulfill some of these team functions. First of all, established work procedures, as pointed out by Boguslaw and Porter (1962), dictate much of the team functions. For instance, the protocol of the so-called "ABC" or airway, breathing, and circulation used in resuscitating cardiac arrest patients, specifies goal and action priorities for resuscitation personnel. Secondly, similar to other medical settings, extensive on-job training and experience in emergency medical care provide personnel with the ability to anticipate the needs of others and what they will do next without explicit (*i.e.*, verbal and gestural) communications. Thirdly, in emergency medical care settings, care givers have continuous visual and auditory contact with each other. (Similar observations were made by Hutchins, 1995, about ship navigation teams.) Team members share the same work space and event space (*i.e.*, what was happening). They can sense, through shared work space and event space, what others are doing or intend to do. A wait-and-see strategy, for example, can be very effective in avoiding potential conflicts among several people in access to the patient and equipment. However, task complexity in emergency medical care could reduce the effectiveness of these coordination strategies.

In the following the implications of task complexity are discussed in terms of task complexity components identified earlier.

Multiple, Concurrent Tasks

When multiple tasks are attempted concurrently, one of the challenges facing emergency care personnel is to resolve various potential conflicts among the members. The team is prone to problems in team coordination, such as goal conflicts, task interference and competitions for access to the patient.

For example, the intubation procedure usually requires paralyzing the patient (see task description above), but patient paralysis can make other team members' tasks (*e.g.*, neurological examinations) difficult or impossible. When the patient's condition is critical and an intubation has to be carried out, conflicts can arise between the anesthesia care provider's activities and other care givers.

Unlike many other emergency settings (*e.g.*, the emergency management center studied by Moray, Sanderson, and Vicente, 1992), emergency medical personnel have to share limited working areas around the patient. In particular, access to the patient is necessary for many tasks, both for clinical monitoring (*e.g.*, attaching patient sensors) and for treatment (*e.g.*, stopping hemorrhage). Multiple, concurrent tasks create potential challenges for care givers to coordinate the limited patient access among the team members.

Uncertainty

Patient monitoring is an important part of resuscitation that helps to reduce unknown information about the status of the patient and increases the clinician's ability to judge the effect of a treatment. For example, the monitoring information about the patient's exhaled carbon dioxide is often used to determine whether an intubation is successful. The lack of a functional monitor for such information increases the difficulty of verifying the position of the endotracheal tube.

When the physiological status of the patient is uncertain, what the team needs to do can become ambiguous. Conflicts can arise in perception of the tasks that need to be accomplished. As a result, it can be a challenge for a team to achieve one of the important team functions: anticipating other team members' material and information needs. (See team function taxonomy in Fleishman & Zaccaro, 1992.)

Changing Plans

When alternative plans are to be executed, the team may be challenged to form a coherent understanding of when to switch to what alternatives and how tasks are to be distributed, especially when the transition to the contingency plans occur suddenly and under time pressure.

In one of the videotaped cases previously reported (Mackenzie, Craig, Parr, Horst, and the LOTAS Group, 1994), under the pressure to perform a difficult intubation, two anesthesia care providers changed to alternative approaches without informing each other. Unfortunately, each took a course of action conflicting with that taken by the other. Furthermore, the rest of the team was unable to provide timely support as they seemed to have difficulties in understanding what alternatives were initiated or how to coordinate their assistance.

Compressed Work Procedures and High Workload

High workload under time pressure creates challenges not only for individuals but also for all resuscitation personnel to coordinate activities. They may have to deviate from traditions and usual procedures and skip certain tasks in favor of more critical tasks. Such a strategy can create ambiguity in terms of which steps should be skipped and how a team should reorganize its members' activities when often-adopted procedures are not followed.

12.4.1 Coping with Complexity

A number of approaches can be suggested to help teams in emergency medical care cope with task complexity. One approach is training in team coordination. Current training for patient resuscitation personnel in the center studied is primarily oriented towards medical and technical aspects, and not specifically towards the skills of performing in a team environment. Training in explicit communication should reduce the occurrence of failures in team coordination. For example, when novel approaches are adopted or established procedures are modified by the leading members of a team, verbalization can help the rest of the team orient and prepare themselves. Team training in resource management and attitude changes have been advocated for highly skilled teams during crises (*e.g.*, Foushee & Helmreich, 1988; Howard et al, 1992) and in routine surgical operations (*e.g.*, Helmreich & Schaefer, 1994). Although such training is important and needed for teams in emergency care (*e.g.*, Donchin et al, 1995), task complexity poses challenges that require more than changes in attitude and use of resources. Training in explicit communication is needed for the purpose of team coordination to improve team performance in emergency care.

Designing work procedures is another approach to reduce the impact of task complexity, considering that in emergency medical care, few procedures are formalized and enforced. Boguslaw and Porter (1962) found that work procedures play an important role in team coordination. Work procedures can be designed to reduce the ambiguity in terms of task distributions and increase the ability of team members to provide timely assistance in crisis situations. Work procedures can also be used to make certain verbalization mandatory, which can help the team function in situations such as when contingency plans are executed.

12.5 Conclusions

By comparing the task characteristics of one medical procedure at two levels of task urgency, the study reported here suggests several ways in which tasks in emergency medical care are complex: the condition of patients is often critical; the care givers sometimes have to deal with great uncertainty and high workload; and tasks are often technically difficult and executed at fast pace. Procedures that can be carried out sequentially in low-urgency situations often have to be carried out concurrently when task urgency is high. Uncertainty can create discordance in perceived tasks and priorities. The failure or extraordinary difficulty in performing a procedure can induce that adoption of contingency approaches that are novel to some of the care givers. The established or often-adopted solutions may have to be modified or abandoned due to high workload.

Based on the findings of the study, four components of task complexity in emergency medical care were identified: multiple concurrent tasks, uncertainty, the presence of contingency plans, and compressed work procedures with high workload. These components of task complexity in emergency medical care pose challenges for team coordination and increase the potential of breakdowns in team coordination, such as conflicts in access to the patient, goals, and tasks. Two approaches are suggested to help care givers in emergency medical care to cope with task complexity: training in explicit communications, and design of work procedures to facilitate team coordination.