TEAM COORDINATION AND BREAKDOWNS IN A REAL-LIFE STRESSFUL ENVIRONMENT

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This paper describes a study of team coordination and its breakdowns in a complex and dynamic work environment. Sixteen videotaped cases of real-life trauma patient resuscitation in a trauma center's patient admitting areas were analyzed. The findings from the study suggest that highly skilled work teams used a variety of ways to coordinate, many of which were non-verbal and implicit. Breakdowns in coordination occurred in several stressful situations, and the lack of explicit, verbal communications could be a major contributing factor. The paper characterizes the situations where coordination breakdowns were observed, and recommends that the team training be targeted at those situations where verbal communications are essential yet team coordination is prone to breakdowns.

INTRODUCTION

Over the past 20 years, a considerable amount of attention has been directed to various aspects of team coordination, such as communications (*e.g.*, Kanki *et al.*, 1989), decision-making (*e.g.*, Orasanu & Salas, 1993; Rogalski & Samurçay, 1993), team organization (*e.g.*, Morrissette *et al.*, 1975), and task distribution (*e.g.*, Hutchins, 1989). Nevertheless, our understanding is still very limited of how teams coordinate in real life situations, especially in those that are stressful and occur during crises. Little information is currently available on (1) the strategies used by practitioners to achieve coordinated activities and (2) the nature of the situations in which coordination breakdowns occur. 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.

To answer these two questions, video recordings made during real trauma patient resuscitation in a level-I shock trauma center were reviewed and analyzed. This paper describes the methodologies and findings of video analysis used.

METHOD AND MATERIALS

Trauma patient resuscitation is a specialized domain in which critically ill or injured patients are resuscitated and treated in a dedicated facility. In the center studied, the personnel in a typical team can be divided into three crews: surgical, anesthesia, and nursing, each with its own crew leader. The surgical crew has one or two surgeons, one of which is the assigned team leader, and an emergency medicine fellow. The anesthesia crew has a nurse anesthetist and one or two anesthesiologists. The nursing crew has one or two nurses and a trauma technician.

Materials Video recordings analyzed were from the video library of real trauma patient resuscitation made during a period of four years in a level-I trauma center. Resuscitation teams were situated in the patient admitting areas (see Figure 1 for an overview of the areas) and were surrounded by resuscitation equipment (*e.g.*, intravenous fluids and airway management and monitoring equipment).

The video recordings were from a fixed miniature video camera suspended from the ceiling, with microphones mounted immediately above the patient's head and feet. The video images were overlayed with patient physiological data, which were directly obtained from patient monitoring equipment (for detailed description, see Mackenzie *et al.*, 1994). The attending anesthesiologist started the recording voluntarily, just prior to the arrival of the patient. Along with video tapes, the participants of a case were requested to submit patient records for later review. The patient records contained basic information about the patient status prior to admission and treatment received (such as drug names and doses).

The participants and non-participant subject matter experts were requested to review video tapes and to provide commentaries, usually within a week. Interviews were conducted for a small number of cases where what had occurred appeared to be unclear. Over 100 cases were so video taped over the three year period, and they covered a wide variety of cases and team compositions.

Video analysis Analysis efforts were focused on the following two objectives: (1) categorizing ways in which team co-

ordination was achieved, and (2) hypothesizing the nature of breakdowns in team coordination. To achieve these two objectives, three types of critical incidents were selected: decision points, high workload periods, and apparent problems in team coordination.

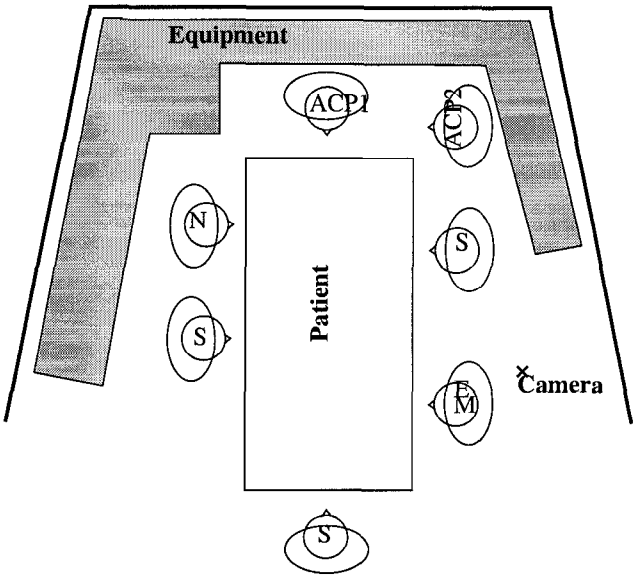

Figure 1: Admitting area layout. The schematic shows camera position (on the ceiling) and personnel. ACP: anesthesia care provider, S: surgeon, N: nurse, EM: emergency medicine physician. Note that the locations of the team members and the composition of the team were not fixed.

FINDINGS

Ten cases in the video library were analyzed in details. These ten cases were selected due to the existence of large amount of commentaries from subject matter experts and the occurrences of critical incidents. However, the selection of the cases was not in any systematic manner and thus subject to sampling biases.

Strategies of Coordination

The findings related to coordination strategies that were used by resuscitation teams are reported in two separate areas: *task coordination*, or the distribution and delegation of tasks, and *information flow*, or the passage of information regarding patient status and contingency plans.

Task coordination During the course of resuscitating a trauma patient, many physical tasks were performed. Some of them had to be coordinated among team members within a crew or across crews. This was so either because the tasks needed synchronous effort from multiple people (*e.g.*, lifting the patient), or because the tasks relied on preconditions (*e.g.*, suctioning equipment must be ready before usage), or because multiple tasks need to be accomplished within a short period of time (*e.g.*, establish the airway and restore blood circulation).

Several forms of non-communication task coordination activities were noted in video analysis. Five of them are listed below. Note that the following forms are not mutually exclusive.

Following the protocols . Established practices (sometimes codified as protocols, such as the Advanced Trauma Life Support protocol), specify task distributions and priorities, immediate goals, and problems to be treated. The tasks to be done by each team member are clear. Without much communication, in almost every case, the surgical, anesthesia, and nursing crews commence their activities after the patient arrived. We observed clear task distributions among the crews in resuscitation teams at the beginning of each patient admission, despite the uncertainty about the patient's status.

Following the leader . Team members determined what they should do by watching the leader. The activities of the team leader can be viewed in some sense as the "medium" through which the team leader passed information (such as instructions) to the rest of the team. If not occupied, we observed that team members tended to follow the attention foci of team leaders. Needed materials or help were provided often without explicit solicitation.

Anticipation . The team members were also found to provide unsolicited assistance through the anticipation of the team leader's response to the patient's physiological events. A gagging sound, in one case, led an assistant to offer a suctioning catheter in anticipation that the patient would vomit soon and the anesthesia crew member would have to use that device to clear the patient's airway. Thus the shared physical event space became a medium of communication for the team. The prerequisite, of course, was the ability to understand the significance of patient events. The workspace itself is also a medium through which the teams coordinated. We often observed that team members, while not under instruction to perform specific tasks, scanned the workspace and perceived tasks needed to be carried out. In one case, for example, upon seeing an unopened package which would be used soon, a team member began to open the package and set up the device inside the package.

Activity monitoring . The interdependencies of tasks shared by a team mean that one member's tasks could sometimes only commence after the success of another member's tasks. (For example, surgeons can only begin certain procedures of resuscitation after the patient is anesthetized.) Thus monitoring the progress of an other member's tasks not only made it possible to compensate for a teammate's performance, but also gave lead information to prepare for the next step.

In many cases, the surgical crew did not announce their plans, however, the anesthesia crew inferred what needed to be done from the activities of the other crew. For example, during the review of the video tapes of a case, one participant in that case revealed that the conversation between two surgical crew members provided cues of what the surgical crew would do next, even though the conversation was not directed at the anesthesia crew.

These strategies of task coordination, without the use of explicit (verbal or gestural) communications, enabled the re-

suscitation teams to perform smoothly in most situations.

Information flow One of the most interesting aspects of team coordination is the explicit, verbal communications regarding situational assessment and future plans, even though such communications were relatively rare. In the situations where such information flow was detected, we found most of the communications had clear indications that the team was at a decision point. The team members voluntarily provided their views of the situation based on the decisions that the teams were facing at the time. For example, in one case when the patient was still not paralysed 90 seconds (the usual duration) after the injection of drugs, several team members, without request, provided their assessment of the patient condition and of the reasons why the patient had not been paralysed. In another case, while an anesthesia care provider was determining whether the patient was receiving oxygen, the surgeon provided his assessment of the situation unsolicited by saying that "the patient was stable."

The amount of verbal communications varied greatly among different teams. Some team leaders verbalized their plans clearly while other team leaders let the team members to infer their goals and intentions through actions. This factor of leadership style will not be reported here, but clearly it influenced the information flow within a team.

Coordination Breakdowns

Considering the uncertainty and task difficulties involved in trauma patient resuscitation, the team coordination was adequate in the majority of the cases we analysed. However, breakdowns in team coordination were observed in a number of crisis situations. We will report these breakdowns in the following three types of situations: (1) when there was pressure to seek alternative solutions, (2) when an unexpected, non-routine procedure was initiated, and (3) when there was a diffusion in responsibility.

Pressure to seek alternative solutions In this type of situation, extreme difficulties or unexpected patient responses were encountered and prevented the implementation of routine procedures. When the patient condition was deteriorating rapidly, the team was under pressure to find an alternative solution and to act immediately. Figure 2 illustrates one such incident. In this case the patient had a gun shot wound to the lower abdomen. The patient's condition required immediate intubation (the passage of a tracheal breathing tube) to enable controlled ventilation, which required paralysing the patient. The regular route to achieve this for the anesthesia crew was to wait for the surgical crew to gain venous access to the patient (phase A), as drugs to paralyse the patient were usually injected intravenously. However, difficulty in achieving this (due to previous use of veins for intravenous drug abuse) and rapidly declining patient conditions (unrecordable blood pressure, weak pulse, and combativeness due to agonal status) forced the anesthesia crew (with two members, ACP1 and ACP2) to examine alternatives.

During phase B (which represented a length of 20 seconds), the two anesthesia crew members implemented a line of action conflicting with each other's action. No attempt was made by either anesthesia crew member to communicate the problems or discuss action plans during this phase. The intentions and the objectives of each anesthesia crew member could only be inferred after their action plans were started.

Initiation of unexpected, non-routine procedures This type of incident arose when unexpected non-routine and novel solutions were attempted. During phase C in Figure 2, for example, one of the anesthesia crew members decided to use a non-routine method (nasal intubation) of achieving airway access. This method required special materials that had not been anticipated in advance by the supporting members of the team. No announcement was made about the adoption of the non-routine method. As a result, the ability of the supporting members of the team to provide assistance was compromised. Coordination breakdowns in this type of incident were marked by the lack of anticipatory help from the team members, delays in preparing materials, and unnecessary pauses in the team leader's activities to obtain assistance.

Diffusion in responsibility In critical circumstances during patient resuscitation, a diagnostic procedure or a treatment plan may have to be abandoned if the patient condition is too unstable. Such changes in plans occur during crises and under great time pressure. The team may have difficulties in adjusting itself from a diagnostic mode to action mode. Figure 3 shows one type of such scenario. During phase A, the anesthesia crew (labelled as ACP in Figure 3) concentrated on determining a critical task condition (whether or not the patient's lungs were being oxygenated), during which time the surgical crew (S) was assessing the patient condition and the nursing crew (N) was standing by, ready to provide assistance. After about 5 minutes the patient condition became critical (due to the lack of oxygen input), and the anesthesia crew decided to abort the process of obtaining further diagnostic cues. A sudden change of action (removal of the endo-tracheal tube or ET tube) was taken, without informing the rest of the team in advance during phase A. The inability of the rest of the team to anticipate this sudden change in plan prevented them adjusting their responsibilities accordingly, and resulted in the omission of a critical step (applying cricoid pressure to prevent regurgitation of stomach content into the lungs after the ET tube was removed).

Summary of strategies for team coordination and types of coordination breakdowns To summarize on the strategies of team coordination, verbal communications can be viewed as one of many media that the team used to communicate. These types of media include, in addition to utterance and explicit gestures, (1) activities, (2) workspace, (3) events, (4) foci of attention. These media were possible because team members worked in closed physical workspaces. Although not sufficient in all occasions, they provide an efficient means for the team to coordinate.

The coordination break downs that our video analysis iden-

tified can be described in the following four forms: (1) conflicting plans, (2) inadequate support in crisis situations, (3) inadequate verbalization of problems, and (4) lack of task delegation. Their occurrence indicates gaps between what was needed and what the team had done in terms of team coordination.

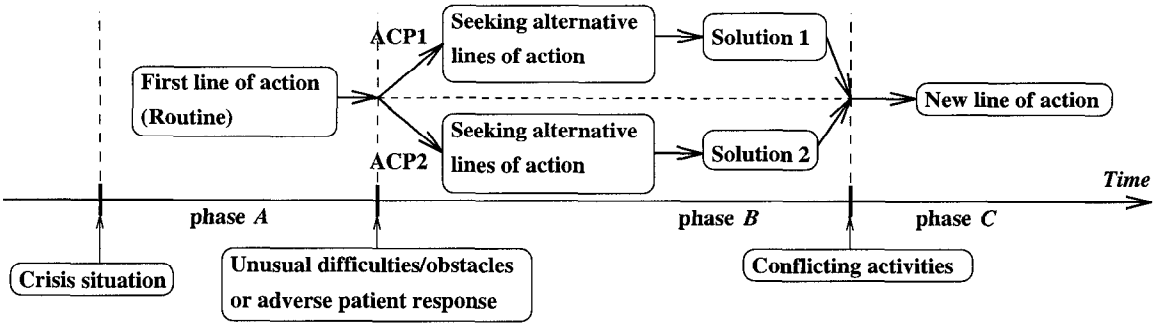

Figure 2: Coordination breakdowns when team encountering unexpected obstacle(s). Two anesthesia care providers are labelled as ACP1 and ACP2.

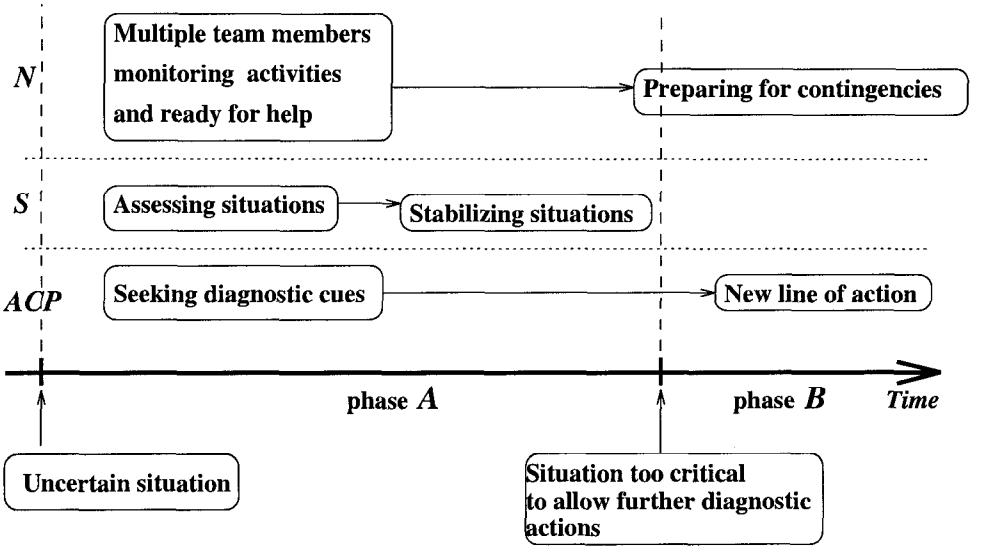

Figure 3: Coordination breakdowns when a sudden change of action occurred. N, S, and ACP represent three lines of activities of the nursing, surgical, and anesthesia crews, respectively.

DISCUSSIONS

The video recordings in our study show that team coordination was achieved in most situations with minimum explicit, verbal communications. When team coordination broke down, it often occurred in situations where there was a lack of explicit communication. In the following, we evaluate these findings against three previous studies done by Serfaty et al (1993), Orasanu (1990), and Segal (1994).

In studies of team coordination patterns under stressful and unstressful situations, Serfaty et al (1993) found that high performance teams were able to adapt their coordination strategies in stressful situations to reduce the cost of explicit communications. It appears that the teams in our study had adapted to the implicit coordination due to the high workload in many situations. Although no quantitative comparison was made between high stress and low stress situations, our observations show that in non-stressful situations, verbal communications contained considerable amount of non-essential information, some of which did not relate directly to the case involved. Such an adaption could probably be better explained by the adaption of workload management, as described by Sperandio (1971) in his analysis of communications between air traffic controllers and pilots.

Orasanu (1990) also contrasts team activities between high and low performance teams. Her major finding was that the content of communications was different between high and low performance teams. High performance teams communicated explicitly about problems and plans. However, the small amount of verbal communications in the cases that we recorded

did not allow us to compare across different scenarios.

Segal's study (1994) of non-verbal communications had similar findings to ours. He found that visual monitoring of team mates' activities was an important part of team coordination. Through the analysis of visual checking patterns, Segal provided quantitative data to support the notion that visible activity is an essential part of team work.

There are several implications of our findings for workplace design. Similar to what Segal (1994) argues, one has to beware of implicit communication channels, as they had important roles in team coordination in our studies. Practitioners utilized various non-verbal media for coordination: through activities monitoring and through shared event space. These media have important functional roles, including allowing team members to compensate for team mates and to schedule their own activities. The ability to monitor on-going activities and events also enables the team to have a coherent shared mental models (Cannon-Bowers *et al.*, 1991; Orasanu, 1990), thus team members could provide needed information and support without an explicit request.

Our findings also provide guidance to studies of team activities in simulated environments. On the one hand, the current study highlights the importance of non-verbal communications and various types of medium used in communication. Stripping these methods of communication away in a laboratory study, for example, could dramatically change how a team coordinate and impose extra workload on the team. Consequently, the problems in coordination observed in such a simulated setting may have a very limited validity in settings like emergency rooms. On the other hand, understanding the three types of scenarios where coordination breakdowns were observed could lead investigators to focus on these scenarios and understand more about coordination breakdowns.

CONCLUSIONS

In analysing team performance retrospectively, with or without the aid of recording media, one may tend to look for the break downs in team coordination. But one should also address the question of how it is possible for a team to coordinate in complex, dynamic work environment. We believe that in order to understand breakdowns, we should first understand how team coordination can be achieved at all. Only with such a background can we understand how a team should coordinate, and why in some cases coordination breaks down.

Resuscitation teams use non-verbal ways to achieve coordination in most situations efficiently. Breakdowns do occur, however, when unexpected obstacles arise, or novel solutions are adopted, or changes in plans occur, particularly during crisis situations and under extreme time pressure. We should acknowledge the advantage and the important role of non-verbal media that team members could use in their coordination (c.f. Segal, 1994), while at the same time be aware that explicit, verbal communications are crucial in certain situations. The training of teams could target those situations where communication is essential and they may improve team coordinations in crises.

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REFERENCES

Cannon-Bowers, J. A., Tannenbaum, S. I., Salas, E., and Converse, S. A. (1991). Toward an integration of training theory and technique. *Human Factors*, **33**, 281–292.

Hutchins, E. (1989). The technology of team navigation. In: Galeglier, J., Kraut, R. E., and Egido, C. (Eds.), *Intellectual Teamwork: Social and Technical Bases of Cooperative Work*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Kanki, B. G., Lozito, S., and Foushee, H. C. (1989). Communication indices of crew coordination. *Aviation, Space, and Environmental Medicine*, **60**, 56–60.

Mackenzie, C. F., Craig, G. R., Parr, M. J., Horst, R., and the LOTAS Group. (1994). Video analysis of two emergency tracheal intubations identifies flawed decision making. *Anesthesiology*, **81**, 911–919.

Morrissette, J. O., Hornseth, J. P., and Shellar, K. (1975). Team organization and monitoring performance. *Human Factors*, **17**, 296–300.

Orasanu, J. (1990). *Shared mental models and crew decision making*. Tech. rept. 46. Cognitive Science Laboratory, Princeton University, Princeton, NJ.

Orasanu, J., and Salas, E. (1993). Team decision making in complex environments. In: Klein, G. A., Orasanu, J., Calderwood, R., and Zsambok, C. E. (Eds.), *Decision Making in Action: Models and Methods*. Norwood, NJ: Ablex.

Rogalski, J., and Samurçay, R. (1993). Analysing communication in complex distributed decision-making. *Ergonomics*, **36**, 1329–1343.

Segal, L. D. (1994). Actions speak louder than words: How pilots use nonverbal information for crew communications. In: *Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting*, 21–25.

Serfaty, D., Entin, E. E., and Volpe, C. (1993). Adaptation to stress in team decision-making and coordination. In: *Proceedings of the Human Factors and Ergnomics Society 37th Annual meeting*, 1228–1232, vol. 2. Santa Monica, CA: Human Factors and Ergnomics Society.

Sperandio, J. C. (1971). Variation of operator's strategies and regulating effects on workload. *Ergonomics*, **14**, 571–577.