

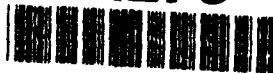


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DATE: November 8, 1993

TO: ONR grant co-invest/consultants/interested parties

FROM: Colin Mackenzie

Enclosed is the 10th quarterly report.

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ONR Grant #N00014-91-J-1540

Report Date: November 4, 1993 Quarter #: 10

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Title: Development and Enhancement of a Model of Performance and Decision Making Under Stress in a Real Life Setting

Institution: University of Maryland at Baltimore and
Maryland Institute for Emergency Medical Systems

Current staff with percent effort of each on project:

Colin F. Mackenzie	22%	Peter Hu	5%
William Bernhard	5%	Paul Delaney	5%
Cliff Boehm	5%	Denise Ovelgone	50%
Brian McAlary	5%	Robert Durocher	50%
Allen Cyna	5%		
Sandy Hunter	5%	<u>Sub-contract Man-Made Systems Corp.</u>	
Andy Trohanis	5%		
Jim Brown	5%	Richard Horst	15%
		David Mahaffey	20%

Undergraduate Research Assistants (URAs) (these positions ended as of September 1, 1993)

Linda Hawkes	40 hrs/week (through August, 1993)
Terry Smith	40 hrs/week (through August, 1993)
Dennis Wood	40 hrs/week (through August, 1993)

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Navy 10th Quarterly Report

The primary activities on this project between August 1st and October 31, 1993 were as follows:

1. We continued video analyses of trauma patient intubation with support from anesthesiologist subject matter experts (SMEs). The focus was on two types of analysis - SMEs' minute-by-minute subjective ratings of stressors and perceived stress, and "independent reviews" of intubation procedures and anesthesiology performance. The subjective ratings, and associated commentaries, are being collected from both the anesthesiologist who participated in the video-taped case (A passes) and from other anesthesiologists who are familiar with the trauma treatment environment (B passes) but who did not participate in the particular case under review. The independent reviews of intubation are conducted by non-participant SME's utilizing the questionnaire form that was enclosed in the last quarterly report. This questionnaire solicits observational information and expert judgments regarding intubation milestones and practices, the appropriateness of treatment approaches, and the effectiveness of team work and trauma team communications.
2. We proceeded with data analysis on several fronts, focusing on a rework and expansion of our earlier correlational analyses of data from the Post-Trauma Treatment Questionnaire (PTQ) and our categorization analyses of verbal communications.
3. We documented our current status, analyses planned for the remaining six months of the present 36-month period of performance, and additional issues that could be addressed during a proposed one-year renewal of the present grant. We developed and submitted a proposal to ONR for this one-year add-on. The data analysis summary below is a modified version of that presented in this proposal, focusing here on current status and plans for the next six months.
4. We received reviewers comments on our paper, "Video Analysis of Two Emergency Tracheal Intubation Cases Identifies Errors and Inappropriate Decision-making," which had been submitted to the journal, *Anesthesiology*. We are presently revising this paper for resubmittal. We proceeded in writing up papers on our data acquisition methodology, video data analysis methodology, and PTQ results.
5. Dr. Mackenzie gave the following presentations of our work at scientific conferences:
 - "Group Decision-Making During Trauma Patient Resuscitation and Anesthesia," presented at the annual meeting of the Human Factors and Ergonomics Society in Seattle, WA, in October, 1993. This presentation was part of a symposium entitled "Analysis of Error in Complex Decision-Making Tasks." The paper that was published in the Proceedings of this conference was enclosed with our last quarterly report.
 - "Stressors Occurring During Emergency Tracheal Intubation," presented at the Emergency Medicine and Critical Care Society meeting in Cambridge, England, September, 1993.

- "Performance of Trauma Anesthesiologists Assessed by a Synthetic Work Environment," presented at the American Society of Anesthesiologists Annual Scientific Meeting in Washington, DC, October, 1993.

We also have been invited to participate in a Symposium, "Human Factors and Cognitive Aspects of Intensive Medical Care," which is being organized for the August, 1994 meeting of the International Ergonomics Association in Toronto. We responded by submitting an abstract entitled, "Communications During Trauma Patient Resuscitation."

6. We responded to the UMAB Institutional Review Board's (IRB) questions regarding a protocol to carry out Holter monitoring (heart rate, rhythm, and electrocardiogram waveform analysis) and ambulatory blood pressure monitoring of trauma anesthesiologists during patient management. Such physiological measures would provide objective measures of stress that could be related to the sort of retrospective subjective ratings of stress that we have been obtaining. If this protocol is approved, we hope to collect these physiological data in selected cases over the next six months. Substantive analyses of these data would, however, be dependent on our securing additional funding (e.g., the one-year renewal). We have spent an enormous amount of time dealing with administrative issues related to IRB questions about the renewal of our approval. We were requested to comply with Quality Assurance guidelines and the protocol renewal was sent again to the Hospital legal authorities. We hope that this hurdle will shortly be cleared.

Status of Data Acquisition

No new cases were video taped in the last quarter. We have been focusing our attention on analyzing the considerable volume of data that is presently on-hand. The three Undergraduate Research Assistant positions were terminated, as planned, on September 1, 1993. The two graduate research assistants continue at their previous levels of involvement.

There were concerns brought up again about medical-legal issues related to the videotaping. Dr Mackenzie has met with the Administration, Legal, Nursing and Medical Groups, and re-explained the project. Dr Mackenzie has also discussed the project again with the admitting area staff, the operating room staff, the Nurse Anesthetists, and the Anesthesiologists. He has reported data to the Quality Assurance Committee and to the Directors Office of Shock Trauma. It is to be hoped with this renewal of discussions with non-participant personnel that they are now in a better position to understand this project.

Status of Data Analyses

The following presentation is organized by research issues. Some of these issues were of interest from the very beginning of the project and others have emerged as we pursued available data and contemplated the results of initial analyses. For each research issue we summarize the current status of our analyses and estimate what more can be accomplished in the remaining six months of the current three-year period of performance.

Factors Influencing Perceived Stress

1) Predicting Minute-to-Minute Perceived Stress from Subjective Ratings of Various Stressors

The subjective ratings of stressors and perceived stress that were derived from retrospective video analyses are being examined in several ways. These ratings are being examined with a neural network analysis that attempts to predict the perceived stress rating from the six stressor ratings (e.g., noise, interactions with the surgical team, interactions among the anesthesiology team, time constraints, workload, and diagnostic uncertainty) that we have been collecting. Of interest is the relative salience of each of these factors in accounting for perceived stress, as well as the total variance accounted for by these six factors. The neural network analysis was conducted previously on a subset of these data and proved to be very encouraging. Our initial analysis included only nine cases in which 174 sets of subjective stressor ratings were made during the tracheal intubation sequence. These preliminary analyses demonstrated an 86% accuracy in prediction of overall perceived stress. This was better than predictions obtained using multiple regression analysis.

We believe that neural networks predictions will become even more robust with the greatly increased data that can now be used for training the neural networks. We have videotaped 65 tracheal intubations, so that we expect to have at least seven times more subjective stressor ratings to predict overall stress. These additional sets of subjective stressor ratings can be used for training the single layer neural networks using different training steps, starting weight vectors, and different combinations of patient data sets. This expanded analysis is now in progress and will be completed and reported on in the next six months.

Profiles of the severity of various stressors are also being compiled across cases, using the beginning and end of intubation as anchor points. These profiles will confirm or disconfirm our hypotheses that intubation is the most stressful aspect of even routine cases. If this basic hypothesis is confirmed, these profiles will then be contrasted with the ratings from the post-trauma questionnaire and also compared between participant and non-participant SME's, between emergency and elective intubation cases, and for cases involving high and low severity of patient injury. These analyses will also be completed in the remaining months of the current period of performance.

The subjective ratings data are being utilized in a number of other analyses in which we are interested in how other dependent measures vary with perceived stress. For example, verbal communications may be grouped and categorized separately based on the level of the perceived stress ratings. As described below, we hope to validate these subjective ratings of stress by demonstrating their relationship with objective physiological indices of stress obtained via ambulatory monitoring from a sample of anesthesiologists as they treat patients.

2) Effects of Experience, Fatigue, and Severity of Patient Injury on Post-Treatment Session Ratings of Stress

Spearman rank order (i.e., non-parametric) correlations have been completed for all pairs of variables on the Post-Trauma Treatment Questionnaire (PTQ). Not surprisingly, there were

significant positive correlations between injury severity scores and ratings of perceived stress and case difficulty. Additionally, it seems clear from our findings that personal experience and experience with team members (an aspect of team-work) are very important in reducing perceived difficulty, stress and in decreasing the number of errors. The more time that has elapsed since working on a similar case, the more likely the anesthesiologist is to commit judgmental errors. Assessment of team experience shows that the greater the time since an anesthesiologist has worked with a team leader, the higher the stress rating for the next case they work on together. In addition, the longer it is since the two have worked together, the greater the rating of case difficulty.

With regard to performance, there is a positive correlation between ratings of own performance and team work and there is a positive correlation between case difficulty and stress. More misjudgments are made the longer it is since patient care was last given. This suggests that refresher courses, such as the use of simulator practice may be helpful. The data also suggest that augmentation of interactions and communications between team members, such as occurs during crisis resource management training, may have a positive effect on individual and team performance. Patient care may also benefit since case difficulty was perceived as being less when interactions and communications were favorable.

We are presently examining the distributions of responses to each item on the questionnaire in order to determine which variables can be included in parametric statistical analyses. Multiple regressions analyses are being conducted for selected subgroups of variables, to determine to what extent *combinations* of the more objective measures predict particular subjective ratings and whether additional variance is accounted for in comparison to the simple correlations. We are also looking more closely at the effects of self-reported fatigue. These analyses will be completed in the next several weeks.

3) Objective Measures of Stress (Physiological Measures from Anesthesiologists)

We have long felt the need for more objective measures of anesthesiologist stress. It is feasible to instrument the Attending Anesthesiologist (or other team member) with ambulatory physiological monitoring equipment that records indices associated with stress and anxiety (e.g., ECG, respiration, skin conductance, blood pressure) in real-time. These physiological signs of stress could then be correlated with measures that we are now collecting, including retrospective subjective ratings, post-treatment questionnaire responses, and performance measures. In addition to serving as a check on the veracity of the various retrospective measures that we are presently obtaining, such data may allow us to better account for individual differences or transient stressors that exert their influence on decision-making at some later time during a case.

Stress Effects on Performance

1) The Nature of Self-reported Errors and Misjudgments

Anesthesiology team (i.e., lead anesthesiologist, CRNA) comments from the post-trauma questionnaires have been examined for self-reports of misjudgments or aspects of patient management that, in retrospect, the care-provider would perform differently. The intent is to characterize the types of human error that occur in trauma anesthesia, identify root causes where

possible, and determine to what extent the care-giver is aware (or willing to self-report) these performance shortcomings. A preliminary report of these self-reports are presented in (Mackenzie, et. al., 1993, the aforementioned paper that was published in the Proceedings of the Human Factors and Ergonomics Society).

In the 88 cases represented, there were 16 instances of self-reported misjudgments and 14 instances of patient management choices that were recognized as non-optimal. None resulted in adverse patient outcomes. Categorization of these shortcomings in terms of knowledge-base problems, procedural problems, and problems due to insufficient information on which to base a sound judgment, indicated a clear preponderance of procedural problems, i.e., omission of or deviation from usual procedures or standard practices. Examples included not realizing that a ventilator switch was inappropriately set until the patient was connected to it, not pre-oxygenating the patient adequately prior to intubation, failing to immobilize the head of a spinal injured patient prior to intubating, not immediately using certain available monitors when the patient's condition indicated the need for it, and failing to immediately perform clinical checks that would have revealed an esophageal intubation. The types of problems acknowledged by trauma anesthesia personnel were, therefore, indicative of errors that can occur when the decision-maker is rushed or distracted, rather than errors due to a lack of knowledge or relevant experience.

More detailed analyses of these self-reports are ongoing, based on the audio taped commentaries collected from "A" and "B" pass SME video analyses of the cases in question. In addition, these self-reports of performance problems are being contrasted with the observations of independent SME reviewers, derived from the Independent Intubation Procedures Review. We anticipate that these analyses will be completed in the remaining six months of the present period of performance.

2) Relationship Between Self-Reported Errors/Misjudgments and Independent Reviews of Intubation Procedures

Analyses to-date of the Independent Reviews of Intubation Procedures have proven enlightening. The results of initial analyses have been reported in Mackenzie, et. al., 1993. We analyzed 22 videotapes of emergency (12 patients) and elective (11 patients) tracheal intubation. We viewed the videotapes to determine if various procedural checks were carried out before, during and after tracheal intubation and compared the checks made for emergency and elective tracheal intubation. We also documented timing of the achievement of various milestones during the intubation sequence.

In each category there were fewer activities performed for emergency than elective intubation. The differences in procedural checks performed before elective and emergency intubation were significant ($p < 0.05$). Among the procedures that were omitted in preparation for emergency intubation was placement of monitors of patient physiological data including O_2 saturation and end-tidal CO_2 . The omission of the end-tidal CO_2 (ETCO₂) monitor in one patient resulted in failure to detect an esophageal intubation for several minutes, and in another patient, monitoring of ETCO₂ could have identified an erroneous diagnosis of misplacement of an esophageal obturator device (This device is used in field emergency airway management). So the task shedding and short-cuts that were taken from usual procedural checks resulted in important

cascades of adverse consequences for the patient. During tracheal intubation, task shedding also occurred with adverse consequences that potentiated the procedural errors occurring in preparation for emergency intubation. The task most frequently shed during tracheal intubation was for the anesthesia care provider to delegate listening to the chest to another non-anesthesia member of the trauma team. In 9 of 12 emergency tracheal intubation, the anesthesia care provider did not listen to the chest. In one instance, this perpetuated the failure to detect the esophageal intubation. These were therefore significant procedural errors that should be able to be corrected with feedback and training for the anesthesia care providers.

In addition to procedural errors, there were three knowledge-based errors. These were not as easy to identify as the procedural errors. All three knowledge-based errors occurred in association with emergency tracheal intubation and concerned dosages of drugs given and route of administration of the drug. Multiple (3-4) stressors were noted in two of these three instances in which knowledge-based errors occurred. In elective intubation, no knowledge-based errors were identified and no more than two (among six that were looked for) stressors were found in any elective tracheal intubation.

We also compared timing of certain landmarks in the intubation sequence. There were significant differences ($p < 0.05$ unpaired t-test) between elective and emergency tracheal intubation in duration of pre-oxygenation of the patient before induction of anesthesia and direct laryngoscopy (instrumentation necessary to pass the tracheal tube through the vocal cords). Pre-oxygenation is a safety precaution to ensure that O_2 levels remain adequate after anesthesia is induced and during the period of direct laryngoscopy and passage of the tracheal tube through the vocal cords (when no oxygen can be given). The shorter duration of pre-oxygenation occurs in the situation when it may be most advantageous. Equally, it may, in some circumstances, be more appropriate to proceed expeditiously with emergency intubation and forego prolonged preparations. These contingencies need further exploration.

There was a significant difference in the interval between starting to ventilate the patient and looking at the end-tidal CO_2 monitor (detection of $ETCO_2$ is the 'gold standard' that confirms that the tracheal tube is in the windpipe not the esophagus). This is a clinically important difference. It occurred because the $ETCO_2$ monitor is immediately behind the anesthesia care providers and also because the sample port for CO_2 is not present in the manual ventilating circuit used immediately before and after tracheal intubation. Only when the patient is connected to the mechanical ventilator is $ETCO_2$ monitored. There are ergonomic and logistical problems that should be easily rectified. We have recommended implementing both procedural and instrumentation changes in Shock Trauma to prevent recurrence of this delay in placing and observing monitors. We do not have videotapes of anesthesiology performance since these changes in $ETCO_2$ monitors were recommended.

3) Relationship between Subjective Ratings of Stress and Performance as Judged by Independent Experts

Some of the items on the Independent Review of Intubation Procedures form can be interpreted as measures of performance, some even quantitative measures, based on expert observation. We have not as yet made good use of these performance measures either in relating them to the subjective ratings and explanatory commentaries obtained from the participating anesthesiologists

(A passes) or in utilizing them in the process of modeling emergency tracheal intubation performance. We will begin such analyses as time permits in the next six months, but are not likely to reach a satisfactory point of closure without follow-on funding.

Strategies for Coping with Stress

1) Team Communication

Team communications are being coded and categorized as described in previous quarterly reports. The initial results of these analyses are reported (Mackenzie, et. al., 1993). The intent is to examine the effects of stress on team communications and identify effective coping strategies that involve verbal communications.

Verbal communications among the trauma teams during selected segments of particular cases were encoded by a data analyst upon review of the video tapes. The sound quality was sufficient to allow the large majority of verbalizations to be heard on the tapes. During the segments of interest, all recognizable utterances were transcribed and categorized. The categories of interest here were the following: (1) Task-relevant questions or requests for assistance or information, (2) Answers to such questions or requests for assistance or information, (3) Unsolicited task-relevant information, (4) Directives, instructions, or delegating tasks, and (5) Comments conveying a plan or strategy. For the purpose of analyzing communications associated with airway management, we examined several minute segments prior to, during, and immediately after the sequence of intubation activities. Verbalizations were encoded for five minutes (or whatever was available) before patient pre-oxygenation, during the entire intubation sequence, and for five minutes after the tracheal tube was secured with tape. The incidence of verbalizations in each category was weighted by the time periods over which they were recorded, in order to directly compare cases, categories, and time segments.

In order to examine the ways in which these trauma teams communicated, we categorized recognizable utterances during several minute segments before, during, and after intubation for a subset of the cases.

There were significantly more utterances during emergency than during elective intubations ($p < 0.05$), and a trend suggesting more verbalizations prior to, than either during or after, intubation. Most interesting, however, was the clear cut differences in the occurrence of comments conveying strategies or plans, and those giving directives, instructions, or delegating tasks. Verbalizations of these types occurred much more often during emergency than during elective cases.

Additional cases are now being coded, with an emphasis on including data from more "elective" intubation (performed in the OR) and cases for which team work or team communications were rated on the post-trauma questionnaire as being sub-par. The incidence of various types of communications is being compared (as before) among pre-, during, and post-intubation segments of cases, between emergency and elective cases, (only now) among cases that were rated by the participants as embodying differing qualities of team work and team communications, and among cases that were described by the retrospective subjective ratings as entailing differing levels of stress. Some but not all of these analyses will be completed within the presently funded period of performance.

- 2) Task Prioritization and Team Coordination (this analysis would be conducted during the proposed one-year add-on).

Modeling Performance

- 1) Confirming Validity of Decision-Trees

The patient physiological data, anesthesia records, and video analyses by independent SME's are being examined in an effort to identify time periods during particular cases when our putative trauma treatment decision trees should have been invoked. These decision trees are based on various physiological abnormalities in trauma patients. We recently completed plotting patient physiological data from all available cases. These data files have now been converted into Paradox-ready format and are stored in our database. Our intent is to focus subsequent video analyses on whether, in fact, the treatment approaches envisioned by the decision trees were utilized, and with what incidence and contingencies alternative approaches were chosen. Some analyses of this sort can be completed during the coming six months, but it is unlikely that we will fully utilize this aspect of our data-base without an add-on period of funding.

- 2) Process Model of Effects of Stress on Emergency Intubation Performance

A subset of anesthesiologists from the LOTAS group have been developing a decision tree model of emergency tracheal intubation. Ultimately, we hope to expand this tree into a predictive quantitative model, using the data derived from the above video analyses conducted in the context of the Independent Reviews of Intubation Procedures, the results of an international survey conducted by the LOTAS Group several years ago, and additional expert judgments to be obtained as needed from LOTAS Group participants. The approach will be to use expert judgments to estimate the response times required to reach various intubation process milestones, as well as the incidence of various treatment choices, under varying levels of stress, to incorporate these estimates and the various stress-inducing contingencies that can occur in a MicroSAINT model, and to compare the resulting predicted response times and treatment choices against actual observed performance. During the next six months, we will likely only get as far as finalizing an initial version of the emergency tracheal intubation decision tree.

- 3) Pattern Recognition by Decision-Makers (this analysis would be conducted during the proposed one-year add-on).

Individual Differences

- 1) Neo-Personality Inventory

Individual anesthesiologist's scores for the six personality facets from the Neo-PI are being correlated with ratings data from the post-trauma questionnaire. An effort is being made to select a relatively homogeneous set of cases (in terms of injury severity and perceived case difficulty) for this initial look at individual differences. If the simple correlations prove interesting, multiple regressions may be necessary to take personality, experience, and fatigue into account simultaneously in predicting the post-trauma session ratings of stress, teamwork, team interactions, and "own performance." We have not given a high priority to these analyses

and will likely not complete them in the next six months.

- 2) Subjective Ratings Broken Down by Individuals (this analysis would be conducted during the proposed one-year add-on).

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