AN INVESTIGATION INTO THE EFFECTS OF CHEMICAL PROTECTIVE EQUIPMENT ON TEAM PROCESS PERFORMANCE DURING SMALL UNIT RESCUE OPERATIONS

Nancy L. Grugle

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Dr. Brian M. Kleiner, Chairman

Dr. Robert C. Williges

Dr. Laurel Allender

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ABSTRACT

Chemical protective clothing is designed to protect the worker by providing a barrier between the individual and the contaminated environment. Unfortunately, the same equipment that is designed to help can often cause heat stress, reduced task efficiency, and reduced range-of-motion for the worker. Teams as well as individuals suffer from these effects resulting in difficulty communicating, increased task completion time, and reduced productivity. Studies investigating the effects of protective clothing generally focus on individuals; however, the military has produced research related to the effects of Mission Oriented Protective Posture (MOPP) on team performance outcomes in an attempt to understand how protective clothing might affect military teams and squads. Previous research has indicated a degradation of team performance as shown by increased task completion time; however, a comprehensive team performance measurement system studies not only the performance outcomes, but also the processes behind the outcomes. In order to provide a more complete understanding of the performance effects of protective clothing and equipment, this investigation focused on the effects of MOPP on the behavioral processes underlying team performance to include adaptability, communication, and coordination. It also attempted to validate previous studies on performance outcomes.

Ten subjects formed five, two-member teams. Subjects were certified EMT's from local rescue squads and were required to perform CPR and spinal injury management (SIM). They performed each task twice—once in their duty uniform and once in MOPP level 4. Team performance was measured using the TARGETS methodology, and event-based team process performance measurement technique. A team performance index score (TPI) was calculated for each team for all four tasks and then used as the dependent measure for the analyses to compare team performance in a duty uniform versus performance in MOPP 4.

Three hypotheses were tested in this study. They were as follows: team process performance will be degraded by MOPP, task completion time will increase as a result of wearing MOPP, and errors will increase as a result of wearing MOPP. Results of six primary analyses indicated that team process performance was not degraded and the number of errors did not increase when teams were wearing MOPP 4. Results did show, however, that task completion time was significantly longer when teams were wearing MOPP 4. The implications of these results are discussed in the thesis and design changes are put forth.

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Chapter 1. Introduction

The purpose of this study is to determine how chemical protective equipment and clothing, specifically, Mission Oriented Protective Posture (MOPP) equipment, affects team performance. For the purposes of this study, team performance is defined as the individual and collective behaviors of two or more individuals carried out to achieve a common goal. It is the sum of tasks performed by individuals and the coordinated actions of team members required to reach a shared goal. The measurement of team performance includes both individual tasks and collective behaviors such as communication and coordination in order to accurately reflect the processes involved in team performance (Shiflett, Eisner, Price, and Schemmer, 1985).

The military utilizes teams at every level of operation ranging from small Army infantry squads to Navy submarine crews. With the recent threats of nuclear, chemical, and biological (NBC) weapons against American soldiers during the Gulf War and other conflicts, it is critical to understand how a team's performance may suffer when performing in a contaminated NBC environment while wearing MOPP equipment. The Army Research Laboratory (ARL) currently uses software called IMPRINT (Improved Performance Research Integration Tool) to model the performance effects of stressors such as MOPP on individual tasks; however, the software does not have the capability to model the effects of MOPP on team performance due to a lack of supporting literature and quantitative data. As a practical application of this research, this study will provide team performance data to extend IMPRINT's current database and improve the overall understanding of the effects of MOPP on team performance.

Past research indicates there is a performance degradation during tasks in which teams are wearing MOPP equipment. This degradation was seen during field exercises, maintenance tasks, and target detection tasks (Draper and Lombardi, 1986; Cox, Jeffers, and Mascarella, 1981; Johnson, 1991). While these studies indicated a degradation effect due to MOPP in terms of increased task completion time, these studies did not provide an indication of the effects of MOPP on the behavioral processes involved in team performance. In order to accurately recognize and diagnose team performance problems, correct these problems through training and systems design, and gain new perspective into the effects of chemical protective clothing on team performance, a process approach must be taken to measuring team performance.

Understanding the effects of MOPP on military team performance can improve performance assessment, system design, and training for the military; however, studying the effects of chemical protective equipment and clothing, in general, on team performance is critical to the performance assessment and training of many types of teams. Although most team performance research efforts focus on military teams, the results of this study are particularly applicable to other civilian team-oriented operations. Fire-fighting teams and chemical disaster clean-up teams, for example, must be able to operate effectively as a team in life-threatening environments while wearing protective clothing. The training of teams to perform successfully in nuclear materials and hazardous waste environments while wearing protective clothing is vital to the safety of millions of people. In addition, protective clothing in uncontaminated environments such as manufacturing "clean rooms" may impact team performance, and as a result, affect production throughput and quality control.

Understanding the effects of protective clothing on team performance outcomes is important for predicting performance levels; understanding how protective clothing affects the processes involved in team performance is critical for improving training, system design, and performance assessment. Studying performance outcomes alone cannot improve team process performance. This study attempted to determine which team processes, if any, were affected by MOPP during a Cardio Pulmonary Resuscitation (CPR) task and a spinal injury management

(SIM) task. Furthermore, this study investigated the performance effects of MOPP based on the role assigned (e.g., team member vs. team leader). The study also attempted to determine which processes were related to performance outcomes and to validate previous research that has identified critical team processes that differentiated successful teams from unsuccessful teams. Specifically, this study attempted to answer the following research questions:

1. What are the effects of MOPP on team process behaviors?
2. How does team process performance vary for different taxons of tasks?
3. What, if any, is there a relationship between the role assigned (e.g. team member vs. team leader) and the effects of MOPP on performance?
4. Which team performance processes are related to performance outcomes?

Based on previous research indicating that team performance was degraded when team members wore MOPP, the following three hypotheses were formulated:

1. Team process performance will be degraded when teams are wearing MOPP 4 as compared to MOPP 0.
2. Completion time will increase when teams are wearing MOPP 4 as compared to MOPP 0.
3. The number of errors committed will increase when teams are wearing MOPP 4 as compared to MOPP 0.

Chapter 2. Literature Review

Protective Clothing

Despite the intention for protective clothing to enhance worker safety or comfort, it can negatively affect a worker through heat stress, reduced task efficiency, and reduced range-of-motion (Adams, Slocum, and Keyserling, 1994). Figure 1 illustrates a model of the causes for negative performance effects on workers wearing protective clothing developed by Adams, et al. (1994).

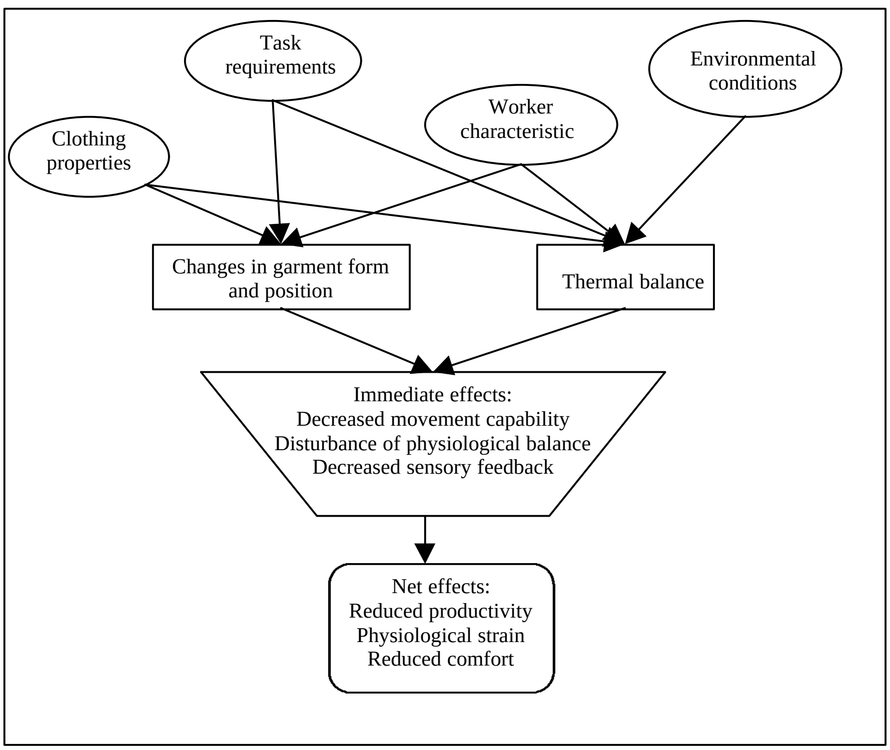


Figure 1. Model for Causes of Negative Performance Effects on Workers Wearing Protective Clothing (adapted from Adams, Slocum and Keyserling, 1994).

Thermal balance is affected by four main factors: clothing properties, task requirements, worker characteristics, and environmental conditions. These same factors, with the exception of environmental conditions, affect changes in garment form and position. The results of these factors can be seen immediately by a reduction of a worker's ability to move (e.g., range of motion), a disruption of physiological balance (e.g., heat stress), and a degradation in sensory feedback (e.g., difficulty hearing or loss of haptic sensation). These immediate results on the operator result in a final net outcome of reduced productivity, physiological strain, and reduced comfort. This model represents the physiological and sensory effects of protective clothing on individuals.

Several studies have been conducted with respect to MOPP in particular. Taylor and Orlansky (1993) found that individual performance is degraded by heat stress, reduced manual dexterity, restricted vision, disrupted communication, and respiratory stress due to the gas mask. The most often studied effects of MOPP are completion time and accuracy. Completion time for maintenance tasks increased by 50% to 70% (Cox, Jeffers, and Mascarella, 1981) and a study by Johnson (1991) found that target detection task completion time increased by 55% to 67%.

A series of studies conducted by Morrissey and Wick (1989), which studied team performance rather than individual performance, identified MOPP as a critical factor in team performance in four types of tasks—visual, fine motor discrete, gross motor light, and communication. In each of these four task types, team performance outcome (i.e., summed task completion time) was degraded when soldiers were wearing MOPP. Wick and Morrissey's (1989) work was an important step in protective clothing research. Task performance was broken into task types for a finer-grained understanding of the nature of performance degradation and task performance was extended to teams. The team performance, however, did not explicitly measure team process.

Team Research

In order to analyze the effects of MOPP and chemical protective equipment, in general, on team performance, the theoretical foundations and components of team performance must be clearly understood. This thesis provides several historically accepted definitions of a team and differentiates teams from both individuals and small groups. A review of research on the critical variables affecting team performance is provided in addition to a description of recent team performance taxonomies and models of team performance. A taxonomy of tasks is then identified in order to classify the rescue tasks performed in this experiment within the IMPRINT framework. A protective clothing taxonomy is established to categorize and compare MOPP with other types of protective clothing. Team performance measurement techniques and methodologies are discussed and, finally, the proposed experimental setup and design are explained.

Team Definition

Teams differ from individuals because teams require synchronized behavior in order to reach a common goal. Team members must possess special skills and knowledge and provide and receive feedback in order to operate effectively. When a team fails, it is not simply because one member failed to meet the requirements; it is because the team could not coordinate the contributions of each team member. Conversely, the dynamics of team performance allow for a team to produce a successful outcome without success by each individual member of the team (Brannick, Roach, and Salas, 1993). Understanding team performance means recognizing the interactions among team members that result in successful and unsuccessful performance (Paris, Salas, and Cannon-Bowers, 1999).

There are many definitions of a team in the literature. Although authors use different terms, there is a general consensus among researchers of what constitutes a "team" versus a "nominal group." The most widely accepted definitions and characteristics of teams are summarized here. Nieva, Fleishman, and Rieck (1978) defined a team as "two or more interdependent individuals performing coordinated tasks toward the achievement of specific task goals." (p. 51) The authors emphasized the two defining characteristics of a team (vs. a nominal group) are a task orientation shared by all team members and the interdependence of team members. This interdependence implies that there is a requirement for coordination and interaction among team members that is not required of individuals in nominal groups.

Glaser, Klaus, and Egerman (1962) also differentiated between nominal groups and teams based on two characteristics. First, nominal groups do not have a rigid or well-defined structure, organization, or communication pattern whereas teams do. Second, group members assume roles during the course of group interaction rather than being initially assigned to a role as is the case for teams. Salas, Dickinson, Converse, and Tannenbaum (1992) added two more characteristics to this distinction between teams and groups: specific roles or functions assigned to each team member and a limited life-span membership for teams. Other researchers have included additional characteristics or conditions that define a team; however, many overlap with previous definitions. Recent research in the 1990's focused on the concept of shared mental models. Teams must adapt to dynamic situations in order to perform successfully. To accomplish this, teams develop a shared understanding of the system and respond accordingly to changes. Team members can anticipate other members' informational needs and then coordinate behaviors (Rouse, Cannon-Bowers, and Salas, 1992 and Paris et al., 1999). Thus, while a nominal group can develop into a team over time, they are qualitatively two different entities.

For the purposes of this study, participants were considered to constitute teams rather than nominal groups. This distinction is based on the definitions provided previously which differentiated teams from nominal groups. The nature of the rescue tasks required that team members be interdependent. It is not possible to perform 2-person CPR or 2-person SIM without communicating and coordinating actions. In this study, for example, the teams were required to synchronize actions such as chest compressions and breathing during CPR as well as synchronize the movements of the backboard and the victim during SIM.   Team members shared the same task orientation. Specific roles were assigned prior to the beginning of the experiment and all team members received identical EMT training. The nature of the tasks required team members to provide and receive feedback about the surrounding environment, the victim's condition, and the rescue procedure. The ability of the team to coordinate actions determined their success during the rescue scenarios. These defining characteristics are accounted for in the experimental setup, providing a legitimate basis for measuring team rather than nominal group performance.

Team Performance Model

Based on a collective definition of what separates a team from individuals and nominal groups, researchers have derived the components of team performance. Nieva, et al. (1978) proposed a conceptual model of team performance as illustrated in Figure 2.

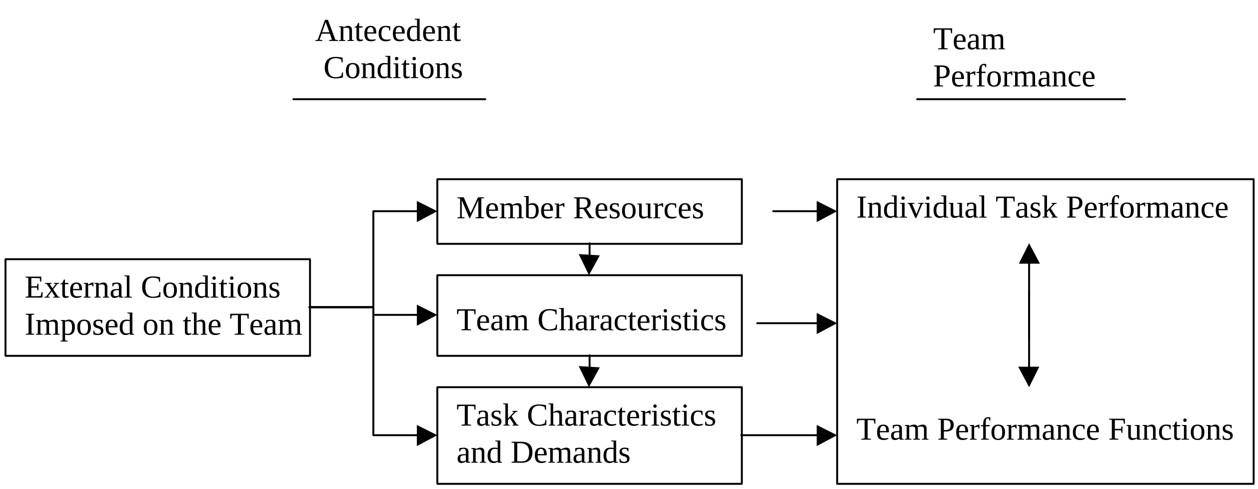


Figure 2. Team Performance Model (adapted from Nieva, et al., 1985)

The authors proposed that team performance has two distinct components—task behaviors and team behaviors. Task behaviors are operations performed by individual team members within their respective roles. Team behaviors comprise the tasks required for the coordination of all individual tasks. Team performance is a function of four classes of variables (antecedent conditions). As indicated in the figure, the factors are external conditions imposed on the team, member resources, team characteristics, and task characteristics and demands. The final team product, or performance, is the "sum" of all the individual task behaviors and the team behaviors. The relative contribution of the individual tasks versus the team behaviors depends on the task structure and how much coordination is required to complete the mission.

Morgan, Glickman, Woodward, Blaiwes, and Salas (1986) clearly defined these two categories of team performance (task behaviors and team behaviors) as "taskwork" and "teamwork." Taskwork refers to tasks performed by individual team members while teamwork refers to the interactions and coordination among team members that are essential for achieving team goals.

Critical Variables

In the attempt to identify the teamwork behaviors critical to team performance, researchers have further refined the general variables such as those mentioned in figure 2 that may affect a team's ability to perform effectively. Morgeson, Aiman-Smith, and Campion (1997) grouped the factors that affect performance into five main categories. They are contextual factors, structural factors, team design factors, process factors, and contingency factors. Contextual factors are those which affect performance in the work environment to include culture and climate or the workplace, training and education systems, reward and information systems. Structural factors are macro-level aspects of the organization's internal environment which affect performance. This includes the physical environment, organizational arrangements, and technological systems. Structural factors are particularly applicable to the military environment where its rigid organizational nature and task environment significantly affect the performance of teams. Team design factors are the characteristics of individual team members that affect performance. Examples are work design, task interdependence, composition, and leadership. Process factors are a broad characterization of the interaction process. These include boundary management, task cohesion, performance norms, communication, potency or team spirit. Contingency factors are those which may degrade team effectiveness. These could include task characteristics, team application, external dependence, autonomy, resource availability, etc. The identification and classification of these factors led to the development of team performance taxonomies and models.

Nieva et al., (1978) identified, through a literature review, nine characteristics or variables that affect group performance. They are group size, group cohesiveness, intra-and inter-group competition and cooperation, communication, standard communication networks, homogeneity/heterogeneity in personality and attitudes, power distribution within the group, and group training. Group size is defined as the number of members in the group. Group cohesiveness is described as the result of all the forces acting on all the members to remain in the group including loyalty, harmony, and identification within the group. Intra- and inter-group competition and cooperation are the degree to which groups compete or cooperate within the group and between other groups. Communication is characterized as verbal interaction among group members. Standard communication networks represent the pattern of communication within the group that is permitted by the investigator. Homogeneity/heterogeneity in personality and attitudes is the degree of likeness in personality and attitudes among members. Homogeneity/heterogeneity in ability is defined as the degree of matching of ability levels as reflected by test scores. Power distribution within the group is represented by the hierarchical structure within the group. And finally, group training involves the training given to the group as a whole.

The authors summarized the hypotheses tested in the literature; however, they emphasized that the results were often conflicting or insufficient to form sound conclusions. In addition, the Nieva, et al.'s review of the literature did not differentiate between teams and groups, thereby limiting the generalizability of these studies. It is important to explain the results, however, because some of these factors may impact team performance.

Group size was positively related to performance for disjunctive and additive tasks; size was negatively related to performance for conjunctive tasks. Disjunctive task performance depends on at least one individual in the group, whereas, additive task performance depends on the combined performance of two or more individuals. Conjunctive tasks require that all members perform well in order to ensure task success. There was a general belief that cohesiveness is positively related to group performance; however, research indicated that cohesiveness itself is not responsible for performance. Performance in cohesive groups was higher for groups that set higher standards. Cooperation was positively related to performance when high levels of interdependence were required. Communication had positive effects on problem-solving and unstructured tasks; however, it had negative effects on highly structured tasks. Homogeneity in personality and attitude was positively related to performance for structured, non-cognitive tasks, whereas heterogeneity was favorable for unstructured and problem-solving tasks. Heterogeneity in ability was better for cognitive tasks. An equal power distribution was positively related to performance in some instances but was affected by several variables. The highest performance was seen in groups that had no leader and were offered a reward; the lowest performance was seen in groups that had no leader and were offered no reward. Group training improved performance for tasks which required interaction among group members. When possible, all of these factors should be considered when empirically testing and measuring team performance. In this study, the factors were controlled as part of the experimental setup (See Chapter 3).

The authors concluded that no universal relationship between group characteristics and performance could be defined for all tasks.   The nature of the task as well the measurement technique significantly impacted the outcome of the studies. Furthermore, this research made no distinction between groups and teams. However, the authors hypothesized the effects of team characteristics on team performance from the literature review in order to develop a provisional taxonomy.

A Taxonomy of Team Performance

Moving toward a team performance measurement system, the next step for researchers was to develop taxonomies and models for describing team performance as a function of critical teamwork behaviors and functions. Nieva et al. (1985) proposed four main categories of team performance functions-- team orientation functions, team organizational functions, team adaptation functions, and team motivational functions. Within each of these categories, the authors described performance dimensions. This categorization resulted in a provisional taxonomy of team performance. The taxonomy is as follows:

I. Orientation functions
   A. Elicitation and distribution of information about team goals
   B. Elicitation and distribution of information about team tasks
   C. Elicitation and distribution of information about member resources and constraints

II. Organizational functions
   A. Matching member resources to task requirements
   B. Response coordination and sequencing of activities
   C. Activity pacing
   D. Priority assignment among tasks
   E. Load balancing of tasks by members

III. Adaptation functions
   A. Mutual critical evaluation and correction of error
   B. Mutual compensatory performance
   C. Mutual compensatory timing
IV. Motivational functions
   A. Development of team norms
   B. Generating acceptance of team performance norms
   C. Establishing team-level performance-rewards linkages
   D. Reinforcement of task orientation
   E. Balancing team orientation with individual competition
   F. Resolution of performance-relevant conflicts

Most of the subsequent research attempting to model team performance was based on this original taxonomy. Fleishman and Zaccaro (1992) adopted and modified Nieva et al.'s provisional taxonomy to propose seven primary team functions. They are orientation, resource distribution, timing, response coordination, motivation, systems monitoring and procedure maintenance. Researchers continued to modify and refine taxonomies such as these in order to adapt them into measurement systems, but further refinements may be necessary. Taxonomies are not enough to measure team performance due to their generalized nature; however, the variables and classifications provide a foundation for quantifying team performance.

Team Performance Measurement Techniques

Performance measurement techniques can take two approaches—outcome measurement and process measurement. A comprehensive team performance measurement system will encompass both process and outcome measures of performance. Outcome measurements focus on the ultimate results of the team's actions whereas process measurements focus on how the tasks are accomplished (Paris et al., 1999). Outcome measurements include completion time, number of errors, and accuracy, for example. Process behaviors include such activities as communication, coordination, and decision-making. Outcome measures are affected by many variables—controlled and uncontrolled, individual and team. Outcome measures can detect a performance problem, but these measures are not useful for determining the cause. (Naval Air Warfare Training Center, no date)

Existing team performance data in IMPRINT were derived from a series of studies by Morrissey and Wick at the Ballistics Research Laboratory from 1988 to 1989. These studies measured military team performance outcomes (i.e., completion time) on soldiers wearing MOPP by summing the individual taskwork times to complete the overall operation. Teamwork or process behaviors were not measured. In order to gain a more comprehensive understanding of overall team performance, this experiment measured how team process behaviors (teamwork skills) were affected by MOPP. Therefore, this thesis focused solely on the development and use of team process measurement techniques.

Morgan et al., (1986) used a process-oriented approach to determine the relationship between teamwork skills and team task performance. They developed the Critical Team Behaviors Form (CTBF) to measure teamwork skills in Navy teams. The seven critical behaviors or skills were as follows: giving suggestions or criticisms, cooperation, communication, team spirit and morale, adaptability, coordination, and acceptance of suggestions or criticism. Within each of these categories, a list of both effective and ineffective behaviors exhibited by teams was identified and then behaviorally rated by observers to measure team process performance. Appendix A contains a comprehensive list of all effective and ineffective behaviors.

In the Navy study, raters observed the occurrence of the critical behaviors and compared the occurrence of the behaviors with team performance outcomes. They found that coordination, communication, and adaptability were the key determinants between teams that performed well and teams that performed poorly (Morgan et al., 1986). Other behaviorally-based teamwork measurement techniques were developed based on this system and adapted for various types of teams.

Fowlkes, Lane, Salas, Franz, and Oser (1994) adapted the critical aircrew coordination behaviors identified by Prince and Salas (in press) and then grouped into seven skill areas as shown in Table 1. The skill areas are team processes that affect team performance for aircrews.

Table 1. Critical Aircrew Coordination Behaviors (adapted from Prince and Salas, in press)

Skill Area	Critical Behaviors
Mission Analysis	Define tasks based on mission requirements.
	Questions data and ideas related to mission accomplishment.
	Devise long-term and short-term plans.
	Identify potential impact of unplanned events on mission.
	Structure tasks, plans, and objectives.
	Critique existing plans.
Adaptability/flexibility	Alter behavior to meet situational demands.
	Be receptive to others' ideas.
	Step in and help others.
	Alter flight plans to meet situational demands.
Leadership	Determine tasks to be assigned.
	Ask for input, discuss problems.
	Focus crew attention to task.
	Tell crew members what to do.
	Inform members of mission progress.
	Provide a legitimate avenue of dissent.
	Provide feedback on crew performance.
Decision Making	Gather pertinent data before making a decision.
	Cross-check information sources.
	Identify alternatives and contingencies
	Anticipate consequences of decisions.
	Provide rationale for decisions.
Assertiveness	Ask questions when uncertain.
	Make suggestions.
	State opinions on decisions/procedures.
	Confront ambiguities and conflicts.
	Advocate a specific course of action.
Situational Awareness	Note deviations.
	Provide information in advance.
	Identify problems/potential problems.
	Demonstrate awareness of task performance of self/others.
	Recognize the need for actions.
	Demonstrate ongoing awareness of mission status.
Communication	Provide information as required.
	Provide information when asked.
	Repeat information.
	Use standard terminology.
	Ask for clarification of communication.
	Convey information concisely.
	Verbalize plans for procedures/maneuvers.
	Use nonverbal communication appropriately.
	Acknowledge communications.

Stout, Salas, and Carson (1994) conducted a study to determine which of the aircrew coordination behaviors were significantly correlated with mission performance. The study used a low-fidelity flight simulator to test the process and outcome performance of 2-person pilot and copilot teams. They determined through behavioral ratings that all process dimensions were significantly related to mission performance for the pilot. For the copilot, all dimensions but two (mission analysis and assertiveness) were significantly correlated with mission performance. Another behaviorally based study by Brannick, Prince, Prince, and Salas (1995) concluded that of the seven critical aircrew coordination behaviors, only three dimensions were important for team effectiveness—assertiveness, decision making, and communication.

An important conclusion to draw from the varied results of previous team process studies is that team performance processes are task-dependent. The processes that are important in one study may not be important in another study simply because the task does not demand the use of that team process. Therefore, it is imperative that researchers be cautious about generalizing results of team process performance studies across different tasks.

In contrast to the behaviorally-based team process measurement systems which rely heavily on observer ratings, Fowlkes, et al. (1994) developed an event-based measurement methodology called TARGETs (Targeted Acceptable Responses to Generated Events of Tasks) to measure team process performance. The methodology involves observing and recording acceptable responses to each event on a checklist. The observer does not behaviorally rate performance; he or she simply marks the absence or presence of scripted behaviors. The goal of this measurement methodology is to provide operationally relevant team tasks and link team performance to task-related behaviors. This technique controls task stimuli by providing events as cues to elicit desired behaviors from the team. Generally, scenario scripts are written in order to ensure that all desired team skills are cued during a particular task. The technique minimizes observer judgment by using a checklist of appropriate responses. Each response, or TARGET, is marked as a “hit” or “miss” during the task operation.

Fowlkes et al. (1994) conducted a study using the TARGETs methodology to rate aircrew performance and determine the reliability and sensitivity of the method. They used the critical aircrew coordination behaviors as the desired team skills to be observed and then translated those behaviors into specific observable “targets” that a non-subject-matter expert could easily observe. Results showed the method had an internal reliability of $r = .985$ and an inter-rater reliability of $r = .94$. The authors emphasize that the TARGETS methodology is applicable to studies that meet the following criteria: a) sequencing of team member interdependencies, inputs, and so forth can be fairly well predicted and worked out; b) team members have explicit roles; c) team members are assembled to achieve a specific goal; d) the performance score is based on the behavior of team members who are cross-trained.

An overall team performance score can be obtained by determining the overall proportion of hits to misses. Additionally, separate scores can be determined for specific groups of targets. For example, to determine a team performance score for communication, the targets requiring communication behaviors can be grouped together and analyzed separately from the overall score. This feature of the TARGETS methodology permits an analysis of a variety of team processes. Because this study was designed to meet the above criteria, the TARGETS methodology was used to measure team process performance in this experiment.

A Task Taxonomy

As explained in the previous section, the measurement of team process is task-dependent. In order to generalize the results of this study to tasks other than CPR and SIM, the individual tasks and subtasks must be categorized into a task taxonomy. IMPRINT uses nine taxonomic categories (taxons) to describe a task. A task can be assigned to more than one taxon. Table 2 lists the task taxonomy and provides definitions for each taxon.

Table 2. IMPRINT Task Taxonomy (adapted from *Stressor Review Report* citing Allender, et al., 1997)

Taxon	**Definition**
Visual	Requires using the eyes to identify or separate targets of objects
Numerical	Requires performing arithmetical or mathematical calculations
Cognitive (Problem Solving and Decision Making)	Requires processing information mentally and reaching a conclusion
Fine motor discrete (FMD)	Requires performing a set of distinct actions in a predetermined sequence mainly involving movement of the hands, arms, or feet with little physical effort
Fine motor continuous (FMC)	Requires uninterrupted performance of an action needed to keep a system on a desired path or in a specific location
Gross motor light (GML)	Requires moving the entire body (i.e. not just the hands) to perform an action without expending extensive physical effort
Gross motor heavy (GMH)	Requires expending extensive physical effort of exertion to perform an action
Communication (read and write)	Requires either reading text of numbers that are written somewhere or writing text or numbers that can be read
Communication (oral)	Requires either talking or listening to another person

The CPR and SIM tasks used in this experiment were categorized using this taxonomy. For the CPR task, the team members initially had to check the victim for consciousness, breathing, pulse, and severe bleeding by inspecting the victim. This required visual inspection, cognitive analysis of the victim's condition, fine motor discrete movement, fine motor continuous movement, and oral communication. The physical performance of CPR required oral communication to coordinate actions, gross motor light movement to give chest compressions, fine motor discrete movement to operate the resuscitation mask and bag, and cognitive assessment of the victim's condition throughout the resuscitation. In addition, the rescuers had to adapt to non-routine events which required the same taxons of tasks mentioned above as well as gross motor heavy movement.

The SIM task required the same initial assessment of the victim's condition as the CPR task and can be categorized identically (visual, cognitive, fine motor discrete, fine motor continuous, and oral communication). Securing the victim to the backboard required oral communication to coordinate actions, visual inspection to ensure the victim is secure, fine motor discrete movement to manipulate the board and straps, gross motor light to maneuver the victim onto the backboard, and cognitive decision-making throughout the entire SIM task. Again, the rescuers adapted to non-routine events which require the same taxons of tasks as well as gross motor heavy movement. The classification of the rescue tasks is summarized in Table 3.

Table 3. Taxonomic Classification of Rescue Tasks

Task	**Applicable Taxons**
Cardiopulmonary Resuscitation	Visual Cognitive Fine motor discrete Fine motor continuous Gross motor light Gross motor heavy Communication (oral)
Spinal Injury Management (backboarding)	Visual Cognitive Fine motor discrete Fine motor continuous Gross motor light Gross motor heavy Communication (oral)

As Table 3 indicates, despite the different task requirements, the tasks are classified identically within the task taxonomy detailed in IMPRINT. The categorization of tasks and subtasks will permit an analysis of team performance based on task taxon and provide a measure of internal reliability across the CPR and SIM tasks. By classifying the rescue tasks according to the IMPRINT task taxonomy, the results of this study may be generalized to other tasks that are categorized by any of these taxons.

Based on the information derived from the literature search, an experimental methodology was developed to study the effects of MOPP on team process performance. It is described in detail in Chapter 3.

Chapter 3. Methodology

Purpose

The purpose of this study was to determine the effects of chemical protective clothing, specifically MOPP, on team process performance. Based on the results of previous MOPP research which indicated that MOPP equipment degrades team performance outcomes, the following four research questions were formulated:

1. What are the effects of MOPP on team process behaviors when team members are wearing MOPP?
2. How does team process performance vary for different taxons of tasks?
3. What, if any, is there a relationship between the role assigned (e.g. team member vs. team leader) and the effects of MOPP on performance?
4. Which team performance processes are related to performance outcomes?

Experimental Design

A 3-way, within subject design (2 x 2 x 3) was used to determine any effects of MOPP equipment on team process performance during two rescue tasks (CPR and SIM). The analysis focused on three factors--MOPP level, task scenario, and team process. The two levels of MOPP were MOPP 0 and MOPP 4. The two levels of task scenario were CPR and SIM. The three levels of team process were adaptability, communication, and coordination. The team process labels were chosen based on the literature and are explained in more detail in the independent variable section of this report. Treatment conditions were randomly assigned to control for an order effect. An analysis of variance (ANOVA) was used to determine any main effects or interaction between MOPP level, task scenario, and team process performance. Figure 3 shows the experimental design.

	Task Scenario- CPR			Task Scenario- SIM		
	Adaptability	Communication	Coordination	Adaptability	Communication	Coordination
MOPP 0	T1 T2 T3 T4 T5	T1 T2 T3 T4 T5	T1 T2 T3 T4 T5	T1 T2 T3 T4 T5	T1 T2 T3 T4 T5	T1 T2 T3 T4 T5
MOPP IV	T1 T2 T3 T4 T5	T1 T2 T3 T4 T5	T1 T2 T3 T4 T5	T1 T2 T3 T4 T5	T1 T2 T3 T4 T5	T1 T2 T3 T4 T5

Figure 3. Experimental Design

Procedure

The experimental session began with a brief introduction and description of the purpose of the study. Participants then filled out an informed consent document and were given a pre-experiment questionnaire to determine demographic information, previous rescue experience, and military experience (See Appendix D). Next, teams were given preliminary instructions regarding the proper procedures for donning and wearing MOPP. MOPP adaptation tasks were then performed to ensure that each participant met the initial performance criterion level. A team leader was designated prior to the beginning of the experiment and was told to direct the actions of the other team member during the rescue tasks. The team leader was chosen based on length of experience. If both team members had equal experience, the team leader was chosen randomly. After receiving detailed instructions regarding all experimental procedures, the team members were separated and both rescuers were provided with a written copy of the rescue scenario and the victim's initial condition. Team members were separated prior to the start of the rescue tasks to ensure that no task coordination occurred prior to the start of the experiment. Rescuers had the opportunity to ask the experimenter questions, but were instructed to proceed based on their EMS training regarding any questions about the correct procedure to use. Victims were Virginia Tech students. They were trained on how to behave prior to the experimental session.

Once each team had been provided with the particular scenario, the team was taken to the rescue site and told to begin the rescue. Performance assessment began when rescuers entered the rescue site. Teams completed both task scenarios twice--once while wearing a duty uniform and once while wearing MOPP IV. All team behaviors were recorded by videotape as well as direct observation to ensure that all behaviors were noted and recorded during the experiment. After each individual rescue task was completed, participants were asked to provide a subjective measure of workload using the NASA Task Load Index workload scale. At the conclusion of all four rescue tasks, participants were given a post-experiment questionnaire.

Independent variable: MOPP Level

There are five levels of MOPP. The level of protection depends on the type and number of protective garments worn. Table 4 indicates the various clothing configurations at each MOPP level. The protective garments include the following: overgarment, overboots, mask/hood, and gloves (RB 101-999 T, 1982). MOPP 0 consists of Battle Dress Uniform (BDU) only and includes no protective clothing. Levels 0 and 4 represent minimum and maximum protection, respectively.

Table 4. MOPP Levels

MOPP Level	Overgarment	Overboots	Mask/Hood	Gloves
0	None	None	None	None
1	Worn*	Carried	Carried	Carried
2	Worn*	Worn	Carried	Carried
3	Worn*	Worn	Worn*	Carried
4	Worn closed	Worn	Worn closed	Worn

*overgarment and/or hood worn open or closed based upon the temperature

This experiment tested two levels of protective clothing—a standard duty uniform (MOPP 0) and MOPP 4. Teams wore their standard EMS duty uniform which consists of pants and a t-shirt. It was assumed that performance wearing the appropriate duty uniform did not differ significantly from performance in the military duty uniform (i.e., BDU's). MOPP 4 consisted of the overgarments, gas mask and gloves worn over their duty uniform on loan from the U.S. Army Research Laboratory--HRED. The overboots were not be worn due to the nature of the experimental tasks. The overboots were not expected to affect critical physical movements because the participants were in a controlled climate with carpeted floors, the tasks were of short duration, and mobility over a long distance was not required.

MOPP Adaptation Tasks

To ensure that a participant's unfamiliarity with MOPP did not confound the experiment and to ensure that all subjects began the experiment at the same level of adaptation to MOPP, five adaptation tasks were developed to correspond to the CPR and SIM taxons described earlier (visual, cognitive, fine motor discrete, gross motor heavy, and oral communication). Prior to beginning the experiment, each participant was required to perform five separate adaptation tasks while wearing MOPP. Each participant's performance was scored according to a pre-determined criterion level before being allowed to begin the experiment. The adaptation tasks and criterion are described below.

In order to allow the participant to visually adapt to the gas mask prior to the experiment, participants performed a Stroop task. They were presented with a set of 35 flashcards which displayed color words printed in a conflicting color (e.g., the word "blue" was printed in red ink). Participants were required to state the color of the text rather than the word itself. The criterion level was 100% accuracy.

Cognitive adaptation was measured by the participants' subjective measurement of their own comfort level. Because participants in the pilot study who were unaccustomed to wearing a gas mask often cited claustrophobia and decreased breathing comfort as main concerns when adapting to MOPP, participants were required to wear the gas mask continuously for 15 minutes during the pre-experiment instruction and briefing phase. After 15 minutes, participants were asked if they felt comfortable enough to begin the experiment and were allowed to discuss any concerns they might have. The criterion level was a positive subjective evaluation of their comfort and an affirmative answer to the question "Are you comfortable enough to perform the experiment?"

Communication adaptation was accomplished by requiring the participant to listen to instructions and then answer three instruction-related questions while wearing MOPP. The criterion level was 100% accuracy.

Fine motor continuous adaptation was accomplished by requiring the participants to find and count their own pulse on their neck for 30 seconds. The experimenter confirmed the accuracy of the pulse count by simultaneously checking the participants' pulse on their wrist. The criterion level was accuracy within +/- 2 beats.

Gross motor heavy adaptation was measured by the participants' subjective evaluation of their comfort level after lifting the backboard with a "victim" strapped onto the board. The criterion level was a positive subjective evaluation.

Independent variable: Task Scenario

The experiment required the rescue squad teams to perform two rescue tasks—CPR and SIM. These rescue tasks were chosen due to their applicability to the military and their generalizability to the civilian sector. These types of rescue tasks are performed by military medic teams under NBC conditions, by fire-fighters in situations where smoke inhalation could be deadly, and by search and rescue teams in inclement weather conditions. Each team was required to perform both tasks twice, once in duty uniform (MOPP 0) and once in MOPP 4. The two CPR task scenarios and the two SIM task scenarios varied slightly to prevent any learning effect; however, the difficulty level remained constant (as determined by the Captain of the Virginia Tech Rescue Squad). Participants were presented with the following four rescue scenarios:

CPR Scenario 1: Victim was found lying on floor; victim is not breathing and has no pulse. During the performance of CPR, the victim has a seizure.

CPR Scenario 2: Victim was found lying in bed; the victim must be moved to the floor to begin CPR; however, there is a significant amount of clutter which must first be cleared away.

SIM Scenario 1: Victim was found lying on floor; bystanders indicate that the victim took a fall from a bunkbed; the patient is unresponsive and his/her airway is blocked.

SIM Scenario 2: Victim was in a fight and pushed forcefully against wall; the victim was found standing and has severe pain in his neck. During the backbaording, the victim vomits.

The task scenarios are depicted below. Figure 4 shows a team performing the CPR task with the victim lying on the floor. Figures 5 and 6 show a team performing the SIM task.

Figure 4. A team giving rescue breaths during a CPR task scenario

Figure 5. A team strapping the victim onto the backboard

Figure 6. A team moving the victim during a standing backboarding scenario

Prior to the start of the task, participants were only provided with information regarding the initial condition of the victim such as the victim fell from a bunkbed. All other events contained in the scenario were acted out by the victim or cued by the experimenter throughout the scenario. During the rescues, the team members were notified of the current condition of the victim by the experimenter (e.g., victim now has a pulse, but still is not breathing) and were to proceed appropriately based on the information provided. For the CPR tasks, teams were required to perform 2-person CPR and adapt to changes in the victim's condition until they were notified by the experimenter that the victim had regained a pulse and was breathing. For SIM tasks, teams were required to use a 2-person backboarding technique to prepare the victim for transport in an ambulance and adapt to changes in the victim's condition or environment. The task ended when the experimenter notified the rescuers that an ambulance was present at the scene. A 100% successful performance was defined as completing the rescue with no errors. The level of success was decreased by any increase in completion time and/or by commission of errors.

Teams were required to follow the procedures for CPR as specifically stated in CPR for the Professional Rescuer (1993), with one exception. As noted in the Handbook on the Medical Aspects of NBC Defensive Operations (FM 8-9), ventilation in contaminated environments must be given using a portable resuscitating mask and bag with NBC filter attached. To protect both the victim and rescuer in a contaminated atmosphere, military teams cannot use the traditional mouth-to-mouth technique to ventilate the victim. Therefore, all participants in this experiment used a portable resuscitating mask and bag to ventilate the victim. Teams were required to follow the procedures for SIM as specifically stated in the Emergency Medical Technician: Basic National Standard Curriculum.

Experimental control was accomplished by using the TARGETS methodology. The individual and team behavior requirements for each of the rescue scenarios were scripted out according to Department of EMS standard procedures and verified by the Captain of the Virginia Tech Rescue Squad. To ensure experimental control and timing, all events were cued by the experimenter. Non-routine events such as a seizure during CPR were included to elicit a variety of responses from team members and to elicit adaptability behaviors.

All target behaviors were categorized by task taxon according to the IMPRINT task taxonomy. (See Appendix B) Table 5 shows the frequency of task taxons occurring within each rescue scenario. Results of an ANOVA indicated that there was no statistically significant difference (p = .83) between task taxon frequencies across the four different task scenarios. (See Appendix C) However, there was a statistically significant difference (p = .0002) between the frequency of task taxons within each of the four tasks. This means that there was an unequal representation of task taxons in the four tasks. For example, there was a greater frequency of communication tasks than gross motor heavy tasks in the four task scenarios.

Table 5. Frequency of Task Taxons Across Tasks

Task taxon	**CPR 1**	**CPR 2**	**SIM 1**	**SIM 2**
Visual	6	2	15	13
Cognitive	24	16	19	16
FMD	15	10	27	22
FMC	9	9	9	7
GML	3	3	8	10
Communication	22	15	24	22
GMH	0	1	0	1
Total task taxons	**79**	**56**	**102**	**91**

Independent variable: Team Process

Three team processes were measured—adaptability, communication, and coordination. The team process labels were chosen based on the literature. Two previous studies (Morgan et al., 1986, and Stout et al., 1994) tested the significance of team process behaviors on performance outcome. As previously explained, they both found a significant correlation between several teamwork processes and performance outcome. Although these processes were categorized differently in each individual study, the actual behaviors within the categories were almost indistinguishable and often overlapped. This study used an aggregate set of those significant team processes under the categories of adaptability, communication, and coordination. For purposes of this report, communication was defined as verbal and nonverbal interaction among team members for the purpose of providing information and coordinating actions. Adaptability was defined as the ability to change and adjust behaviors in response to changing task demands, to a changing environment, or to other team member actions. Coordination was defined as behaviors that focus on harmonizing team activities to meet a common goal. The specific teamwork behaviors that were measured under these three categories were adapted from the Critical Aircrew Coordination Behaviors. This particular set of behaviors was selected because the TARGETs methodology used these behaviors to test the method's reliability; however, the behaviors were adapted to fit rescue task scenarios and grouped under the three main categories. Table 6 shows the team process taxonomy used in this study. In general, there was little modification to adaptability and communication behaviors from the Critical Aircrew Coordination Behaviors. The coordination behaviors included behaviors that were previously categorized under mission analysis, leadership, decision-making, assertiveness and situational awareness with some omissions and modifications.

All target behaviors were categorized according to the team process taxonomy. (See Appendix B) Although the four task scenarios required different responses from the rescue team members, an ANOVA determined that there was no significant difference ($p = .50$) in the frequency of team process behaviors across tasks. (See Appendix C) In other words, in terms of team process performance requirements, the tasks were not statistically significantly different.

However, there was a statistically significant difference (p = .0000) between the frequency of team processes within each task. This meant there was an unequal representation of team processes in each task. The frequency of team process behaviors elicited by the scenario scripts is summarized in Table 7.

Table 6. Team Process Behaviors Taxonomy

Team Process	Critical Behaviors
Adaptability	Alter behavior to meet situational demands. Be receptive to team member's ideas. Step in and help team member. Alter plans to meet situational demands.
Communication	Provide information to team member as required. Provide information to team member when asked. Repeat information when necessary. Use standard Dept of EMS terminology. Ask for clarification of communication if necessary. Convey information concisely. Verbalize plans for procedures/maneuvers. Use nonverbal communication appropriately. Acknowledge communications from team member.
Coordination	Determine tasks to be assigned. Ask for input from team member. Focus crew attention to task. Tell crew members what to do. Provide feedback on crew performance. Gather pertinent data before making a decision. Identify alternatives and contingencies. Ask questions when uncertain. Make suggestions. State opinions on decisions/procedures. Confront ambiguities and conflicts. Note deviations. Provide information in advance. Identify problems/potential problems. Recognize the need for actions. Define tasks based on mission requirements.

Table 7. Frequency of Team Process Behaviors

Team process	**CPR 1**	**CPR 2**	**SIM 1**	**SIM 2**
Adaptability	11	7	9	9
Communication	23	24	18	13
Coordination	34	35	28	24
Total process behaviors	68	66	55	46

Inter-rater Reliability of Task Classifications

All target behaviors were categorized by task taxon according to the IMPRINT task taxonomy and by team process as described above. The Captain of VTRS served as a subject matter expert for the classification of all targets to provide a measure of inter-rater reliability between the experimenter and the Captain. Table 8 shows the inter-rater reliability between the two classifications of the tasks.

Table 8. Inter-rater reliability for Task Classfication by Team Process and Task Taxon

Task	Task Taxon	Team Process
CPR 1	.784	.597
CPR 2	.778	.672
SIM 1	.833	.453
SIM 2	.811	.467

The average inter-rater reliability for task taxon across all four tasks was r = 0.8 while the average inter-rater reliability for team process across all four tasks was only r = .547. Because reliability scores of 0.8 or higher are typically acceptable in social science work (Wilson and Corlett, 1990), the experimenter's classification by task taxon was used for the team performance measurement. However, the low inter-rater reliability for team process indicated some discrepancy between the conceptual classification of the rescue tasks by the experimenter and the Captain of the Virginia Tech Rescue Squad. In order to account for the difference in classifications, the ANOVA was run once using the experimenter's classification and once using the SME's classification and the results were then compared to determine if the classifications resulted in different team performance scores.

Experimental Setup

The experimental setup attempted to control for the critical variables identified by Nieva et al., (1985), but did not measure their effect on team performance. The team had two members.

Instructions promoted group cooperation rather than competition. Verbal communication between team members was allowed at all times. The standard communication network was an all-channel network meaning that each member could communicate freely with the other member. Heterogeneity/ homogeneity in personality, attitudes, and ability was difficult to control; however, because teams were comprised of existing staff members from an EMS organization, some similarity was assumed. The power distribution consisted of one team leader responsible for coordinating the actions of the team and one subordinate team member. All team members were cross-trained on how to perform each team member's role, on the goals and objectives of the mission, and on the state of the victim.

In order to legitimately define the participants as a team, interdependence of team members was built into the experimental setup. Interdependence was required because the dynamics of successfully completing the rescue demanded adaptability, coordination, and communication among team members. Team members were assigned to specific roles and those roles remained the same for all tasks. Interdependence of team members was inherent in the tasks. Bowers et al. (1992) explains, "interdependence is imposed when subtasks under the control of each member must be performed during a complex operation." (p. 505) Although the team received information regarding the initial condition of the victim and the surrounding environment, team members were required to communicate with each other, make coordinated decisions, and adapt to dynamic situations in order to achieve successful performance.

Team Performance Measurement

Team process performance was measured using target checksheets for each of the four scripted scenarios. For each event in the scenario, the associated task taxon, team process, and target were identified. For each target identified in the scenario script, the experimenter made an observation of present or absent. The observer also indicated which team member performed the target, leader (L) or member (M). Any errors such as deviation from procedure were also recorded. Figure 7 shows a segment of the target checksheet. (See Appendix B for complete checksheets of all four rescue scenarios)

Figure 7. Segment of Target Checksheet

Event	Task Taxon	Team Process	TARGET	HIT (L/M)
Check scene	Visual		visually scan room for unsafe conditions	
	Cognitive	Coordination	determine if scene is okay	
	Communication	Communication	communicate scene is ok or indicate potential problems	

The checksheet segment above depicts a scripted event that occured during all four rescue tasks. When rescuers first arrived, they were required to check the condition of the scene (i.e., rescue site). This event was broken down into three separate targets. During this task, the team member visually scanned the scene for unsafe conditions, determined if there was a potentially dangerous situation at the scene, and then communicated the condition of the scene to the other member. Each of these targets was categorized according to task taxon and team process, if applicable. Some targets represent individual tasks rather than team tasks and, therefore, are not categorized by team process.

Using a specific checksheet for each rescue scenario, the observer marked each target as a hit or miss and indicated which team member performed the task. The proportion of total hits was then used to calculate the overall team performance score. A quantitative measure of team performance was calculated using a Team Performance Index (TPI) score for each team process type (e.g., $TPI_{adaptability}$, $TPI_{communication}$, $TPI_{coordination}$). The TPI was adapted from the Naval team performance index developed by Dwyer (1992) and is a proportion of hits. The calculation is as follows:

$$TPI = P_H / (P_H + P_M)$$

where P_H = frequency of hits and P_M = frequency of misses. The TPI score reflects the level of team performance on a scale from 0.0 (low) to 1.0 (high). The TPI scores were used as the dependent measure in the ANOVA. In addition, team performance outcomes were measured by completion time, number of errors, and severity of errors. Completion time was calculated from the video recordings. Severity of errors was a rating of each error as determined by the Captain of VTRS.

Subjects

A total of ten participants formed five, two-member teams. Participants were selected from the Virginia Tech Rescue squad, the Southwestern Virginia Mountain Rescue squad, and the Dublin Rescue Squad. All EMS and search and rescue teams were currently certified by the Department of EMS. Although team members were recruited from the same rescue organization, teams were not considered to be pre-existing and were not required to have previously worked with their team. A voluntary human "victim" was used during the CPR and SIM tasks.

The average age of the subjects was 22 years old (SD = 4.47 years). The average rescue experience was 2.45 years and ranged from six months to eight years. Nine of the ten participants were students at Virginia Tech; the other participant was not a student. Nine of the participants had achieved a high school diploma; one participant had received a bachelor's degree. None of the subjects had prior military experience.

Six of the subjects had both trained and performed rescues in protective clothing (firefighter's turnout gear). More than half of the subjects formally trained for rescues once per month; however, seven of the ten subjects had not trained for CPR in the last six months. Four of the ten subjects had not trained for SIM in the last six months. The recency of rescues requiring either CPR or SIM was relatively evenly distributed over a range of one week prior to more than one year ago.

There may be some question about using civilian subjects to investigate the effects of military equipment such as MOPP on team performance; however, the use of civilian subjects was justified for several reasons. To address the concern that civilians were not familiar enough with wearing MOPP to prevent any confounding effects due to adaptation, it is important to note that the MOPP training norm for the U.S. Army is only once each calendar year. (McMahon, 2001). There is no data on the whether military soldiers would be more adapted to MOPP after a one-year lapse between training sessions than civilians would be with no prior MOPP experience. In addition, MOPP adaptation tasks were developed for this study to ensure that all subjects begin the experiment at the same level of adaptation to MOPP.

To address the concern that civilians do not wear MOPP specifically, there are documented instances where civilians use of MOPP may be required. Civilian use of MOPP was recently authorized and implemented by the U.S. Army in Seoul, South Korea. In November 1999, all Department of Defense (DoD) civilian employees and family members in Korea were issued gas masks as part of a comprehensive protective posture program in response to North Korea's chemical warfare capabilities. Mission-essential DoD civilians had previously been given gas masks and protective clothing as part of the same program (Gamble and Johnston, 1999).

Perhaps most convincingly, the use of civilian subjects was justified by the large number and variety of civilian industries that require employees to wear personal protective clothing (PPE) with characteristics similar to MOPP. The next section describes, in detail, the similarity of civilian PPE to MOPP.

Equipment

Industry requirements for personal protective equipment clothing vary depending on the environment and task demands. In order to generalize the results of this study to industries in which people wear protective clothing other than MOPP, the characteristics of MOPP were categorized within a taxonomy of protective clothing. To this end, the protective equipment and clothing from six industries (coal mining, agriculture, semiconductor manufacturing, fire-fighting/EMS, hazardous material clean-up, and the military) was also categorized within this taxonomy to serve as a basis for comparison between industries. These industries were chosen to show the range of occupations which require protective equipment.

The U.S. Department of Health and Human Services developed the Personal Protective Equipment for Hazardous Materials Incidents: A Selection Guide (1984) to assist industry professionals in determining what types of protective clothing are appropriate and necessary for particular job descriptions. It divided the components of chemical protective equipment into respirators and chemical protective clothing. For purposes of this study, the components were combined under the category of Personal Protective Equipment (PPE). The three main components of PPE were as follows: respiratory equipment, chemical protective clothing, and other protective components. Within each of these components were subclassifcations of protective equipment. A taxonomy of PPE was developed based on the classifications described in the selection guide. Figure 8 shows the taxonomy.

I. Respiratory Equipment
    A. Air-purifying respirators
    B. Supplied air respirators
    C. Self-contained breathing apparatus
II. Chemical Protective Clothing
    A. Fully encapsulating suits
    B. Non-encapsulating suits
    C. Aprons
    D. Specialized protective equipment
        1. Fire-fighter's protective clothing
        2. Proximity or approach garments
        3. Flotation gear
        4. Blast and fragmentation suits
        5. Anti-radiation suits
        6. Cooling garments
III. Other Protective Components
    A. Helmets
    B. Gloves
    C. Boots

Figure 8. Taxonomy of PPE

Respiratory equipment has three main components. Air-purifying respirators filter the air from the surrounding atmosphere through cartridges or canisters. Supplied air respirators utilize a compressor or bank of compressed air cylinders and a hose to provide air to the worker from a distance. Self-contained breathing apparatus allow the worker to carry respirable air with them. Respirators have several configurations. At minimum, a respirator contains a facemask that covers the nose and mouth (half-face). It can also consist of a facemask with a face shield (full-face). In addition, a hood or helmet may be attached to the full-face respirator. The appropriate configuration is determined by the environment and task demands.

Chemical protective clothing has four main subclassifcations: fully encapsulating suits, non-encapsulating suits, aprons, and specialized protective clothing. Fully encapsulating suits are one-piece outfits that protect the entire body. Respirators, boots and gloves may be separate or attached. Non-encapsulating suits are two-piece garments consisting of a jacket and hood in addition to pants or bib overalls. Aprons protect the chest and forearms of the worker from splashes and are typically worn in addition to lightweight encapsulating clothing. Specialized protective equipment can be used in place of protective clothing or in combination with protective clothing. The selection guide classified this equipment separately from protective clothing because it was not designed specifically for hazardous materials, but is often used for hazardous materials incidents. Other protective components such as helmets, gloves, and boots are used in addition to the equipment and clothing described above.

Based on the taxonomy described above, the types of PPE required by six industries are categorized in Table 9.   The table served as a basis of comparison between the industries and allowed generalizations to be made from the characteristics of MOPP to other protective equipment required by different industries. The table does not provide specific information on which type of respirators, chemical protective clothing, or other protective equipment are used because requirements for PPE (e.g., weight, material, porosity) may vary within an industry based on a specific job description.   Moreover, the considerable variety of equipment and numerous equipment configurations make the list of PPE used in each industry almost unlimited. The table provides a general overview of the types of equipment used in each industry.

The configurations and type of PPE may differ among industries; however, there are similarities to the general characteristics of MOPP used in the military within all of the industries. Four industries use respirators similar to the military gas mask; three industries use non-encapsulating suits similar to the MOPP overgarment and pants; five industries use some form of gloves; and five industries use some form of boot or overboot.

Table 9. PPE Requirements by Industry Type

Industry	Respiratory Equipment	Chemical protective clothing	Gloves	Boots
Agriculture/ Pesticide application	1. Half-face respirator 2. Face shield	1. Fully encapsulating suits 2. Pants 3. Apron	1. Neoprene gloves 2. Rubber gloves 3. Vinyl gloves	1. Neoprene boots 2. Rubber boots
Coal mining	1.Half-face respirator 2. Full-face respirator	1. Hard Hat 2. Safety glasses 3. Face shields		1. Protective footwear
Fire-fighting/ EMS	1. Self-contained breathing apparatus	1. Pants 2. Coat 3. Hood	1. Kynol gloves 2. Neoprene gloves	1. Fireman's boots
Hazardous material cleanup	1. Self-contained breathing apparatus 2. Full-face respirator 3. Half-face respirator	1. Helmet 2. Protective hood 3. Glasses/goggles 4. Face shields 5. Aprons 6. Fully encapsulating suits 7. Non-encapsulating suits	1. Gloves	1. Boots 2. Toe caps
Military (MOPP)	1. Full-face respirator with hood	1. Non-encapsulating suit 2. Helmet	1. Gloves	1. Overboots
Semiconductor manufacturing	1. Self-contained breathing apparatus 2. Full-face respirator	1. Helmet 2. Protective hood 3. Glasses/goggles 4. Face shields 5. Aprons 6. Fully encapsulating suits 7. Non-encapsulating suits	1. Nomex gloves 2. Kynol gloves 3. Neoprene gloves 4. Cotton gloves	1. Over-the-shoe boots

(adapted from Gittelman, 1988; McAteer, 1985; Nelson, Lefton, and Scott, 1992; Ronk, White, and Linn, 1984)

Although the weight and material characteristics of MOPP do not correspond exactly to PPE in civilian industry, there is variability among weight and material characteristics for PPE used within any given industry. Despite this variability, there was enough similarity between the

PPE used in both military and civilian occupations to generalize the effects of MOPP to other PPE. Moreover, just as the characteristics of MOPP have evolved over time, it is likely that the characteristics of civilian PPE will continue to change as new technology emerges.

MOPP equipment was provided to the participants by ARL-HRED. Overgarments and gloves are sized small, medium, and large and were distributed based on height and build of the participant. Gas masks are not sized and were distributed randomly. Participants were instructed in the proper techniques for donning the equipment and for operating while wearing the equipment. In addition, participants were provided with a portable resuscitating mask and bag and instructed on the proper technique for using the equipment while wearing a gas mask. A backboard, straps, cervical collar, head pads and tape were borrowed from the Virginia Tech Rescue Squad and provided to the participants. Task scenarios were videotaped using Hi-8 video recorders. Three cameras were set up to record the tasks from various angles. Completion time was measured using the counter feature on the cameras.

Chapter 4. Results

As stated in Chapter 3, the goal of this study was to answer the following research questions:

1. What are the effects of MOPP on team process?
2. How does team process performance vary for different taxons of tasks?
3. What, if any, is there a relationship between the role assigned (e.g. team member vs. team leader) and the effects of MOPP on performance?
4. Which team performance processes are related to performance outcomes?

To answer these questions, six primary analyses were conducted. The first analysis focused on the effects of MOPP on team process performance as measured by TPI scores for adaptability, communication, and coordination. The second analysis determined the effects of MOPP on team performance as a function of task taxon. For this analysis, all targets were categorized by task taxon rather than team process and a TPI was calculated for each category of task taxon. The third analysis broke down the TPI scores for adaptability, communication, and coordination into separate scores for team leaders and team members. Two ANOVAs were performed (one for team leaders and one for team members) to determine the effects of MOPP on process performance by individuals rather than teams. The final three analyses focused on the effects of MOPP on task completion time, team errors, and subjective workload ratings using the NASA TLX rating scale.

For all analyses, the general analytical approach was to perform an ANOVA and then conduct hypothesis tests to determine the nature of the main effects and interactions. Alpha was set at 0.05 for all ANOVA and hypothesis tests. Paired t-tests were used for all hypothesis tests in order to minimize the overall correction for Type I error due to the small sample size. The format for all hypothesis tests was as follows:

$H_0 : \mu_1 - \mu_2 = 0$
$H_a : \mu_1 - \mu_2 \neq 0$
$\alpha = 0.05$
reject H_0 if $|t| > t_{.025}$

The next six sections provide detailed results for each analysis described above.

Team Process Performance

The experimental design used to study the effects of MOPP on team process performance was a three-factor, within subjects design. Fixed effects factors were task scenario, team process, and MOPP level. Teams were a random effects factor. All significant effects were isolated using a t-test. The structural model for the design was as follows:

$$Y = \mu + \alpha_i + \beta_j + \delta_k + \gamma_l + \alpha\beta_{ij} + \alpha\delta_{ik} + \beta\delta_{jk} + \alpha\gamma_{il} + \beta\gamma_{jl} + \delta\gamma_{kl} + \alpha\beta\delta_{ijk} + \alpha\beta\gamma_{ijl} + \alpha\delta\gamma_{ikl} + \beta\delta\gamma_{jkl} + \alpha\beta\delta\gamma_{ijkl} + \varepsilon_{m(ijkl)}$$

The sources of variation for the 2 x 3 x 2 design were as follows:

Source	df
<u>Between Subjects</u>	
Team (S)	(n-1) = 4
<u>Within Subject</u>	
Task type (T)	(t-1) = 1
T X S	(t-1)(n-1) = 4
Team process (P)	(p-1) = 2
P X S	(p-1)(n-1) = 8
MOPP level (M)	(m-1) = 1
M X S	(m-1)(n-1) = 4
T X P	(t-1)(p-1) = 2
T X P X S	(t-1)(p-1)(n-1) = 8
T X M	(t-1)(m-1) = 1
T X M X S	(t-1)(m-1)(n-1) = 4
P X M	(p-1)(m-1) = 2
P X M X S	(p-1)(m-1)(n-1) = 8
T X P X M	(t-1)(p-1)(m-1) = 2
T X P X M X S	(t-1)(p-1)(m-1)(n-1) = 8
Total	tpmn-1 = 59

The dependent measure for the ANOVA was the Team Performance Index Score (TPI). A TPI was calculated for each team process—adaptability, communication, and coordination. As stated in Chapter 3, the low inter-rater reliability for the classification of tasks by team process resulted in two calculations of TPI scores—one using the experimenter's classification and one using the SME's classification. Tables 10 and 11 show the $TPI_{adaptability}$,$TPI_{communication}$, and $TPI_{coordination}$ scores for the CPR tasks and SIM tasks, respectively, as determined using the experimenter's classification. Tables 12 and 13 show the TPI scores as determined by the SME's classification.

Table 10. TPI Scores for CPR Tasks (Experimenter)

Team Process	MOPP Level	Team 1	Team 2	Team 3	Team 4	Team 5
Adaptability	0	.571	.75	.714	.750	.500
	4	.917	.587	.583	.429	.714
Communication	0	.583	.667	.652	.640	.600
	4	.84	.708	.800	.500	.792
Coordination	0	.771	.778	.694	.774	.742
	4	.861	.750	.861	.611	.806

Table 11. TPI Scores for SIM tasks (Experimenter)

Team Process	MOPP Level	Team 1	Team 2	Team 3	Team 4	Team 5
Adaptability	0	1	1	1	1	1
	4	1	1	1	1	1
Communication	0	.692	.722	.923	.667	.692
	4	.611	.692	.667	.692	.500
Coordination	0	.565	.889	.958	.815	.522
	4	.556	.913	.63	.565	.481

Table 12. TPI Scores for CPR tasks (SME)

Team Process	MOPP Level	Team 1	Team 2	Team 3	Team 4	Team 5
Adaptability	0	0	1	0	1	1
	4	1	.5	1	0	1
Communication	0	.526	.579	.684	.632	.579
	4	.789	.737	.684	.474	.789
Coordination	0	.654	.667	.577	.524	.619
	4	.587	.692	.810	.5	.731

Table 13. TPI Scores for SIM tasks (SME)

Team Process	MOPP Level	Team 1	Team 2	Team 3	Team 4	Team 5
Adaptability	0	1	0	1	0	1
	4	0	1	0	1	0
Communication	0	.833	.765	.917	.706	.750
	4	.647	.750	.706	.833	.529
Coordination	0	1	.944	1	.944	1
	4	1	1	.889	1	.889

TPI scores utilizing the experimenter's classification ranged from a low score of .429 to a high score of 1; SME scores ranged from 0 to 1.

Two separate ANOVAs were performed using the data from Tables 10 and 11 for the first analysis and the data from Tables 12 and 13 for the second analysis. Results from the ANOVA were used to determine if there was a significant difference between TPI Scores and also to indicate whether the two classifications provided different results. The results for the first ANOVA (experimenter's classification) are shown in Table 14; ANOVA results for the SME classification are shown in Table 15.

Table 14. Analysis of Variance for TPI Scores (Experimenter)

Source	DF	SS	MS	F	P
Task	1	0.10727	0.10727	4.85	0.092
Process	2	0.26226	0.13113	19.25	0.001*
MOPP	1	0.00145	0.00145	0.05	0.828
Team	4	0.12453	0.03113	2.95	0.090
Task*Process	2	0.43825	0.21913	16.55	0.001*
Task*MOPP	1	0.06541	0.06541	2.89	0.165
Task*Team	4	0.08851	0.02213	2.09	0.173
Process*MOPP	2	0.01216	0.00608	2.77	0.122
Process*Team	8	0.05450	0.00681	0.64	0.725
MOPP*Team	4	0.10801	0.02700	2.56	0.120
Task*Process*MOPP	2	0.01709	0.00855	0.81	0.479
Task*Process*Team	8	0.10594	0.01324	1.25	0.378
Task*MOPP*Team	4	0.09061	0.02265	2.14	0.166
Process*MOPP*Team	8	0.01756	0.00220	0.21	0.980
Error	8	0.08451	0.01056		
Total	59	1.57807			

* indicates significance at ($p < 0.05$)

A significant difference was found for the Team Process main effect (p = .001) and for the Task x Process interaction (p = .001).

Table 15. Analysis of Variance for TPI Scores (SME)

Source	DF	SS	MS	F	P
Task	1	0.1040	0.1040	2.54	0.186
Process	2	0.5753	0.2876	12.65	0.003*
MOPP	1	0.0001	0.0001	0.00	0.951
Team	4	0.0766	0.0192	0.08	0.987
Task*Process	2	0.5154	0.2577	19.91	0.001*
Task*MOPP	1	0.1641	0.1641	0.36	0.580
Task*Team	4	0.1639	0.0410	0.16	0.951
Process*MOPP	2	0.0220	0.0110	0.47	0.642
Process*Team	8	0.1819	0.0227	0.09	0.999
MOPP*Team	4	0.1357	0.0339	0.14	0.965
Task*Process*MOPP	2	0.0180	0.0090	0.04	0.965
Task*Process*Team	8	0.1036	0.0129	0.05	1.000
Task*MOPP*Team	4	1.8137	0.4534	1.81	0.221
Process*MOPP*Team	8	0.1885	0.0236	0.09	0.998
Error	8	2.0065	0.2508		
Total	59	6.0695			

* indicates significance at (p< 0.05)

Again, a significant difference was found for the Team Process main effect and for the Task x Process interaction. Because the ANOVA for both classifications yielded the same significant results, the SME classification was used for reliability data only; data from the experimenter's classification was used for all further analyses.

The results of both ANOVAs indicated that there was a significant difference in overall team process performance across all four tasks. In addition, a significant result for the Task x Process interaction indicated that the effect of team process was restricted to either the CPR or SIM task. Hypothesis tests were conducted to determine which team processes were significantly different and which task contained the significant team process difference.

Hypothesis tests were conducted using a paired t-test to isolate the process main effect. Using Excel, the results of the paired t-test for adaptability and communication were as follows:

t-Test: Paired Two Sample for Means

	Adaptability	Communication
Mean	0.83925	0.682
Variance	0.038583671	0.010678842
Observations	20	20
Pearson Correlation	0.292282482	
Hypothesized Mean Difference	0	
df	19	
t Stat	3.636544231	
P(T<=t) two-tail	0.001756129	
t Critical two-tail	2.093024705	

H_0 was rejected at p = .0018. Therefore, it was concluded that team adaptability performance was not equal to team communication performance. Based on the means for each team process, it was concluded that team adaptability performance was significantly better than team communication performance.

The results of the paired t-test for adaptability and coordination were as follows:

t-Test: Paired Two Sample for Means

	Adaptability	Coordination
Mean	0.83925	0.7271
Variance	0.038583671	0.019990621
Observations	20	20
Pearson Correlation	-0.12841842	
Hypothesized Mean Difference	0	
df	19	
t Stat	1.956624516	
P(T<=t) two-tail	0.065251737	
t Critical two-tail	2.093024705	

H_0 was not rejected at p = .065. Based on the p-value, it was concluded that team adaptability was not significantly different from team coordination.

The results of the paired t-test for communication and coordination were as follows:

t-Test: Paired Two Sample for Means

	Communication	Coordination
Mean	0.682	0.7271
Variance	0.010678842	0.019990621
Observations	20	20
Pearson Correlation	0.633336487	
Hypothesized Mean Difference	0	
df	19	
t Stat	-1.82887317	
P(T<=t) two-tail	0.083160291	
t Critical two-tail	2.093024705	

H_0 was not rejected at p = .083. Therefore, it was concluded that team communication performance was not significantly different from team coordination performance.

Figure 9 shows the team process main effect. The graph shows that TPI $_{adaptability}$ is significantly higher than TPI $_{communication}$ or TPI $_{coordination}$.

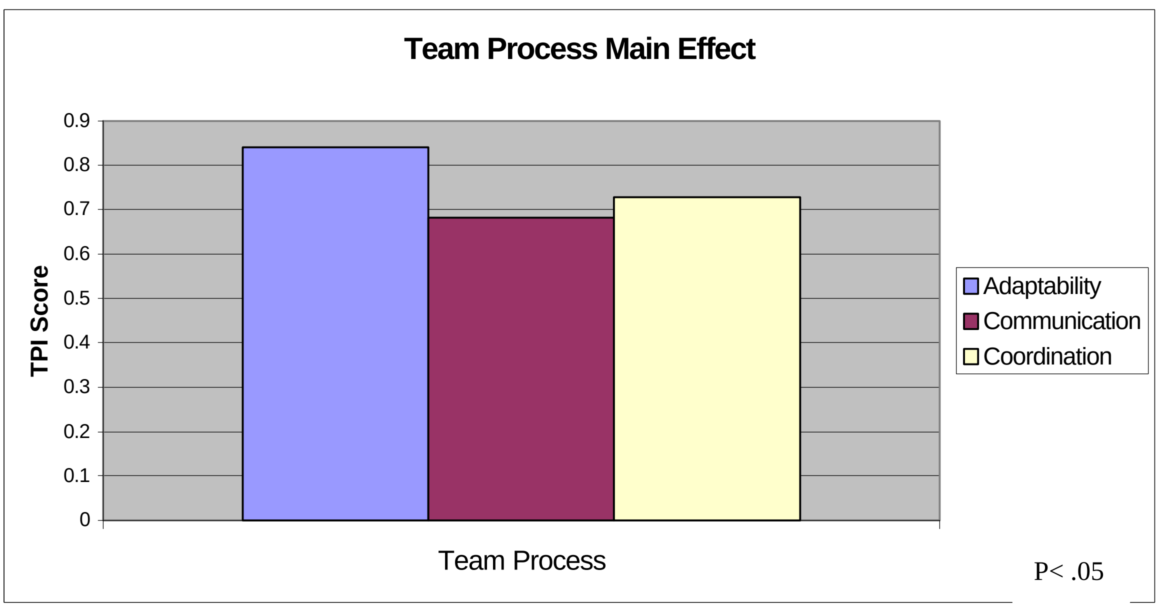


Figure 9. Team performance as a function of team process

In order to analyze the interaction between Team Process and Task type, the effect of task type on team process performance was isolated. Six hypothesis tests were conducted using paired t-tests in Excel. The results for adaptability vs. communication in CPR tasks were as follows:

t-Test: Paired Two Sample for Means

	Adaptability	Communication
Mean	0.6785	0.6782
Variance	0.024030944	0.011561956
Observations	10	10
Pearson Correlation	0.669972619	
Hypothesized Mean Difference	0	
df	9	
t Stat	0.008239213	
P(T<=t) two-tail	0.993605876	
t Critical two-tail	2.262158887	

H_0 was not rejected at p = .008. Therefore, it was concluded that there was no significant difference between adaptability and communication performance during the two CPR tasks. The results for adaptability vs. coordination in CPR tasks were as follows:

t-Test: Paired Two Sample for Means

	Adaptability	Coordination
Mean	0.6785	0.7648
Variance	0.024030944	0.005545511
Observations	10	10
Pearson Correlation	0.514379893	
Hypothesized Mean Difference	0	
df	9	
t Stat	-2.0512499	
P(T<=t) two-tail	0.070471099	
t Critical two-tail	2.262158887	

H_0 was not rejected at p = .07. Therefore, it was concluded that there was no significant difference between adaptability performance and coordination performance during the CPR tasks. The results for communication vs. coordination during CPR tasks were as follows:

t-Test: Paired Two Sample for Means

	Communication	*Coordination*
Mean	0.6782	0.7648
Variance	0.011561956	0.005545511
Observations	10	10
Pearson Correlation	0.853184694	
Hypothesized Mean Difference	0	
df	9	
t Stat	-4.66641671	
P(T<=t) two-tail	0.001174522	
t Critical two-tail	2.262158887	

H_0 was rejected at p = .001 and it was concluded that there was a significant difference between communication and coordination during CPR tasks. Because the mean score for coordination was higher than the mean score for communication, it was concluded that coordination performance was better than communication performance. The results for adaptability vs. communication performance for SIM tasks were as follows:

t-Test: Paired Two Sample for Means

	Adaptability	Communication
Mean	1	0.6858
Variance	0	0.010950178
Observations	10	10
Pearson Correlation		
Hypothesized Mean Difference	0	
df	9	
t Stat	9.495013699	
P(T<=t) two-tail	5.49846E-06	
t Critical two-tail	2.262158887	

H_0 was rejected at p = .0001 and it was concluded that adaptability performance was significantly different than communication performance. Based on the means, it was concluded that adaptability performance was better than communication performance during SIM tasks. The results for adaptability vs. communication were as follows:

t-Test: Paired Two Sample for Means

	Adaptability	Coordination
Mean	1	0.6894
Variance	0	0.033498489
Observations	10	10
Pearson Correlation		
Hypothesized Mean Difference	0	
df	9	
t Stat	5.366471696	
P(T<=t) two-tail	0.000452453	
t Critical two-tail	2.262158887	

H_0 was rejected at p = .0004. It was concluded that adaptability was significantly different than coordination. Based on the means, it was concluded that adaptability performance was better than coordination performance during SIM tasks. The results for communication vs. coordination were as follows:

t-Test: Paired Two Sample for Means

	Communication	*Coordination*
Mean	0.6858	0.6894
Variance	0.010950178	0.033498489
Observations	10	10
Pearson Correlation	0.679913644	
Hypothesized Mean Difference	0	
df	9	
t Stat	-0.083914691	
P(T<=t) two-tail	0.934961144	
t Critical two-tail	2.262158887	

H_0 was not rejected at p =.935. It was concluded that communication was not significantly different than coordination during SIM tasks. Figure 10 shows the task x process interaction.

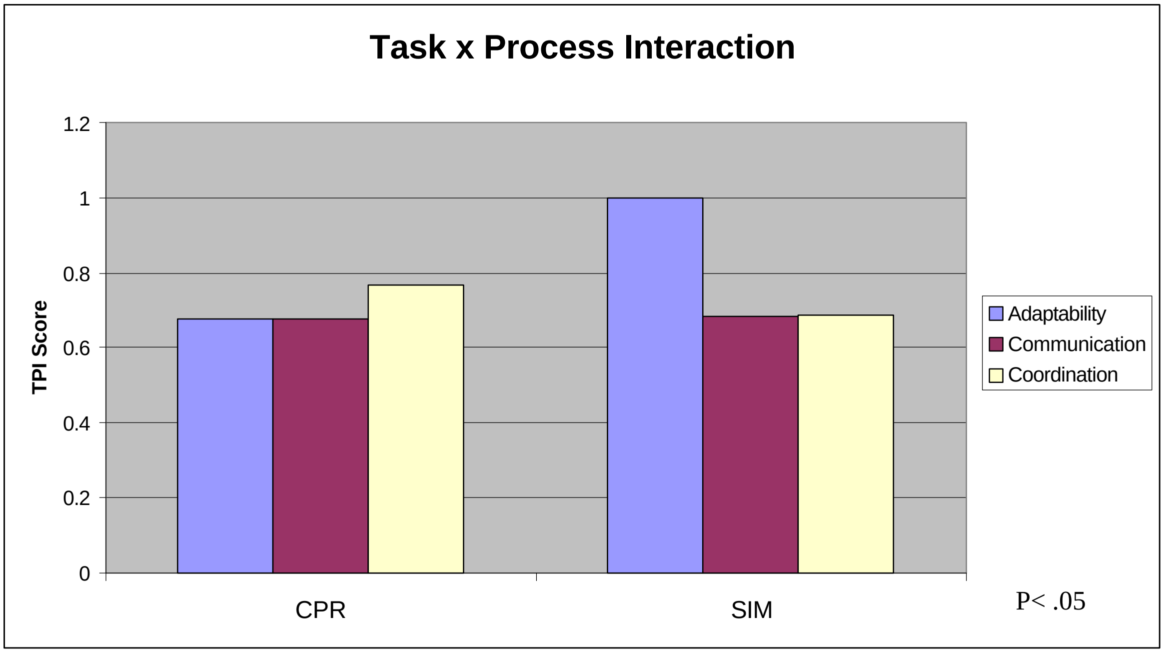


Figure 10. Team performance as a function of task x process interaction

Within the CPR tasks only, coordination performance was significantly better than communication performance. However, within the SIM tasks only, adaptability performance was better than both communication and coordination performance. MOPP level had no significant effect on team performance.

Team Performance as a Function of Task Taxon

In order to determine if team performance differed significantly across task taxons, a 2 x 2 x 7 ANOVA was performed. The three factors were task scenario (CPR, SIM), MOPP level (0, 4), and task taxon (cognitive, communication, FMC, FMD, GMH, GML, visual). TPI was used as the dependent measure. The results are shown in Table 16.

Table 16. Analysis of Variance for TPI as a Function of Task Taxon

Source	DF	SS	MS	F	P
Task	1	0.01692	0.01692	0.08	0.790
MOPP	1	0.00201	0.00201	0.26	0.636
Taxon	6	2.36622	0.39437	9.78	0.000*
Team	4	0.52142	0.13036	1.61	0.205
Task*MOPP	1	0.23069	0.23069	2.70	0.176
Task*Taxon	6	0.84641	0.14107	4.51	0.003*
Task*Team	4	0.83267	0.20817	2.56	0.064
MOPP*Taxon	6	0.01769	0.00295	0.04	1.000
MOPP*Team	4	0.03079	0.00770	0.09	0.983
Taxon*Team	24	0.96773	0.04032	0.50	0.953
Task*MOPP*Taxon	6	0.09572	0.01595	0.20	0.975
Task*MOPP*Team	4	0.34221	0.08555	1.05	0.401
Task*Taxon*Team	24	0.75140	0.03131	0.39	0.988
MOPP*Taxon*Team	24	1.83117	0.07630	0.94	0.560
Error	24	1.94784	0.08116		
Total	139	10.80090			

* indicates significance at p< .05

The results of the ANOVA indicated a significant taxon main effect and a significant taxon x task interaction. A taxon main effect indicated that teams' performance scores for certain taxons was higher than for others. The taxon x task interaction indicates that team performance as a function of task taxon was dependent upon which task was being performed (CPR or SIM). However, MOPP level had no significant effect (p = 1.000) on team performance regardless of the task taxon. These results were consistent with the previous analysis of team performance which indicated that regardless of how tasks were categorized, team performance was not affected by MOPP level. Figure 11 shows the team performance scores as a function of task taxon.

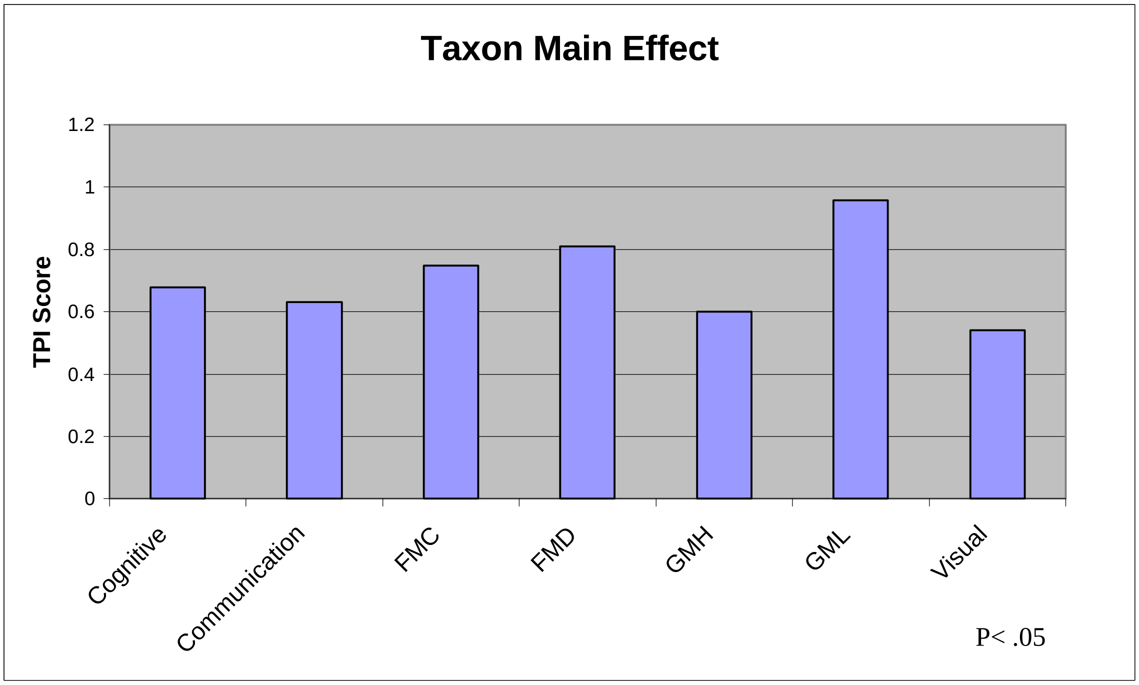


Figure 11. Team performance as a function of task taxon

The graph depicts the level of team performance during certain taxons of tasks. Average team performance scores across all four tasks were highest during GML tasks and were lowest during visual tasks. T-tests were conducted to determine significant differences for the taxon main effect and task x taxon interaction. (See Appendix E for data)

Results from the Taxon main effect t-tests indicated the following: average team performance scores during GML were significantly higher than all other task taxons; performance scores during GML, GMH, and FMD tasks were significantly higher than during cognitive, communication, and visual tasks.

Results from the Task x Taxon interaction for CPR tasks tests indicated the following: team performance scores during FMD and GML tasks were not significantly different; however, performance during both of those task taxons was significantly higher than during all other task taxons.

Results from the Task x Taxon interaction for SIM tasks tests indicated the following: TPI scores associated with performing GML and FMC tasks was not significantly different; however, scores associated with those two task taxons were significantly higher than for all other taxons. Performance scores for both GML and FMC tasks were significantly higher than for FMD tasks. Performance scores associated with cognitive tasks were significantly higher than for communication or visual tasks; performance scores associated with visual tasks was significantly lower than for all tasks except communication. Figure 12 depicts the task x taxon interaction.

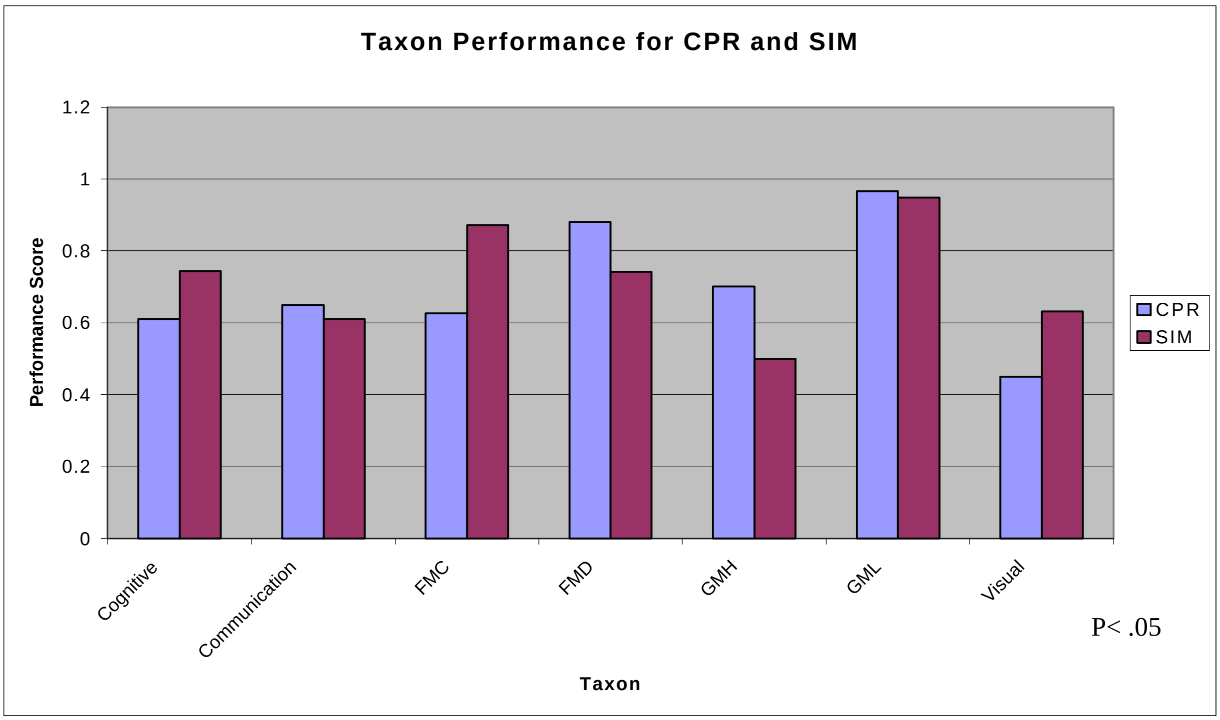


Figure 12. Taxon performance for CPR and SIM

Team Leader and Team Member Performance

In addition to measuring team performance, the performance of team leaders and team members was considered separately to determine whether there was a significant difference in performance by individuals not apparent with teams. Two ANOVAs were conducted, one for leader performance and one for member performance, respectively, using the same structural model as was used for team performance. The results for the team leader performance ANOVA are shown in Table 17.

Table 17. Analysis of Variance for Team Leader Performance

Source	DF	SS	MS	F	P
Task	1	0.35945	0.35945	14.47	0.019*
Process	2	0.17648	0.08824	4.93	0.040*
MOPP	1	0.00757	0.00757	0.12	0.746
Team	4	1.01044	0.25261	12.82	0.001*
Task*Process	2	0.15071	0.07535	7.92	0.013*
Task*MOPP	1	0.11687	0.11687	3.84	0.122
Task*Team	4	0.09933	0.02483	1.26	0.361
Process*MOPP	2	0.01543	0.00771	1.84	0.220
Process*Team	8	0.14325	0.01791	0.91	0.552
MOPP*Team	4	0.25187	0.06297	0.14	0.870
Task*Process*Team	8	0.07615	0.00952	0.48	0.838
Task*MOPP*Team	4	0.12175	0.03044	1.54	0.278
Process*MOPP*Team	8	0.03355	0.00419	0.21	0.979
Error	8	0.15763	0.01970		
Total	59	2.72604			

* indicates significance at ($p < 0.05$)

The results of the ANOVA for leader performance indicated significance for the Task, Process, and Team main effects as well as the Task x Process interaction effect. Hypothesis tests were conducted to isolate the main effects and interaction effect (See Appendix E for all t-test results). Figures 13 and 14 show the task and process main effects, respectively.

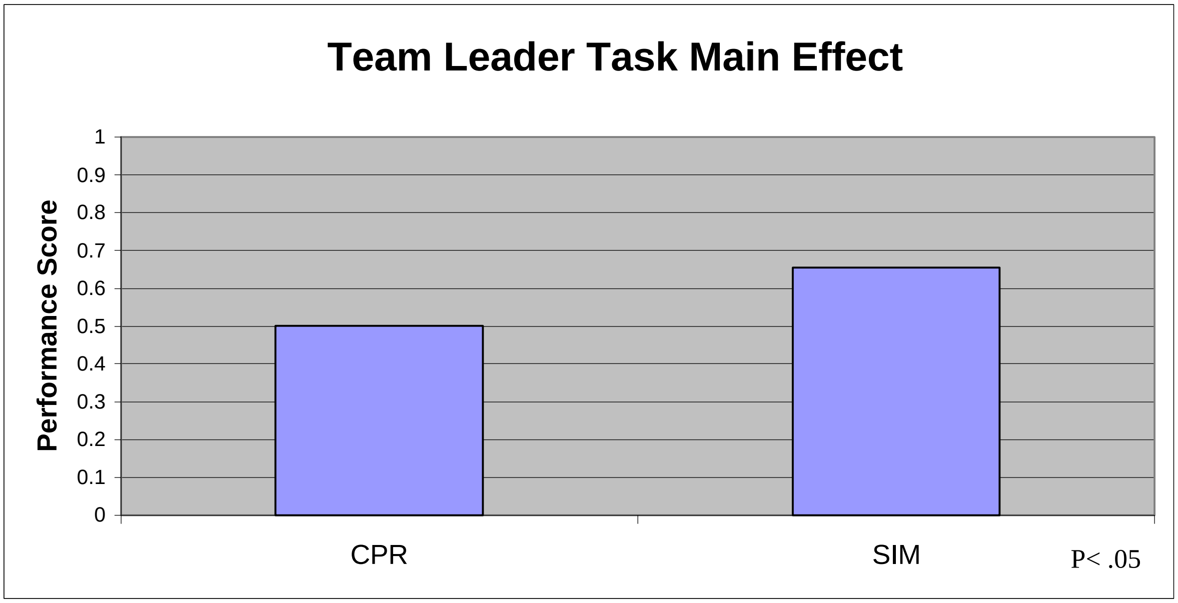


Figure 13. Team leader performance as a function of task

The mean TPI was .500 during CPR tasks and .655 during SIM tasks. . The Task main effect indicated that team leader performance scores were significantly higher for SIM tasks than CPR tasks (p = .0007).

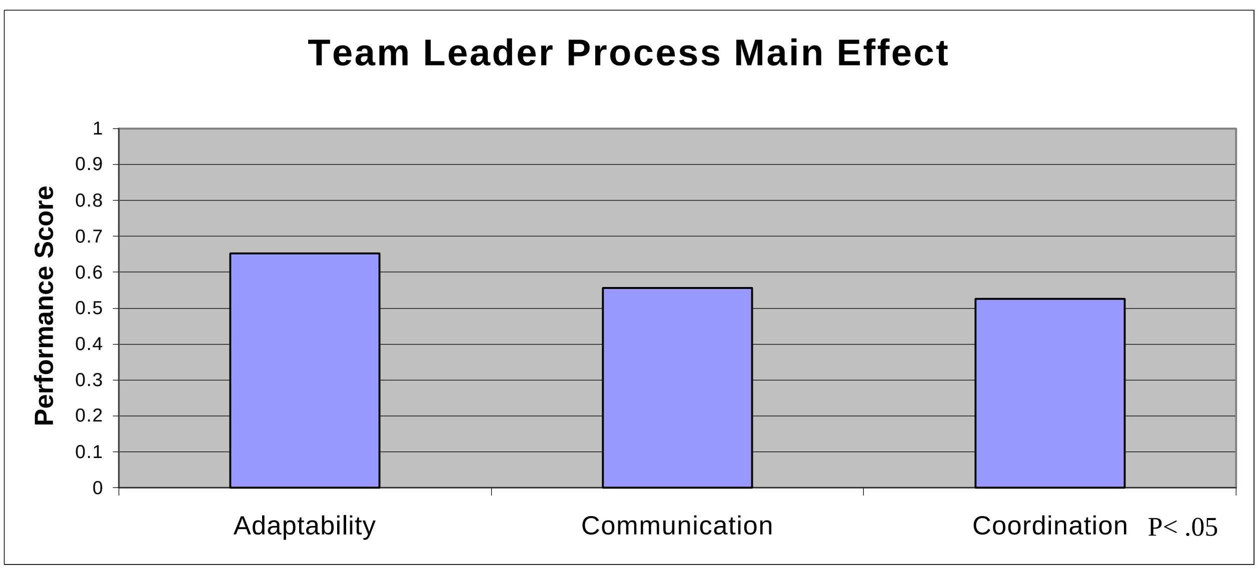


Figure 14. Team leader performance as a function of team process

The mean performance score was .652 for adaptability, .555 for communication, and .526 for coordination. The Process main effect showed significantly higher adaptability performance than either communication (p = .022) or coordination performance (p = .019).

The Team main effect is depicted in Figure 15.

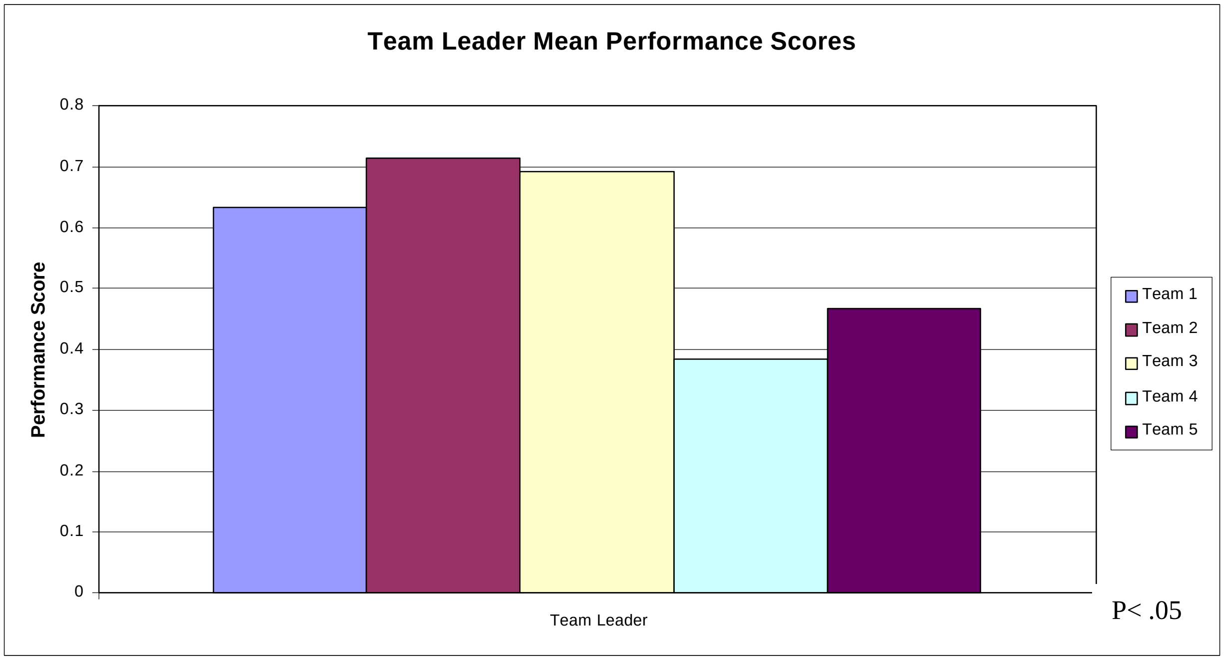


Figure 15. Mean Team Leader Performance Scores

The team leader for Team 2 had the highest mean performance score followed in decreasing order by Team 3, 1, 5, and 4. Team leader scores for Teams 1, 2, and 3 were not significantly different from each other; however, leader scores for Teams 4 and 5 were both significantly different than the first three teams. Team leader scores for Teams 4 and 5 were not significantly different from each other.

T-test results for the task x process interaction indicated that for CPR tasks, there was no significant difference between any team processes. For SIM tasks, adaptability performance was higher than either communication (p = .0002) or coordination (p = .0001). Figure 16 shows the task x process interaction for team leader scores.

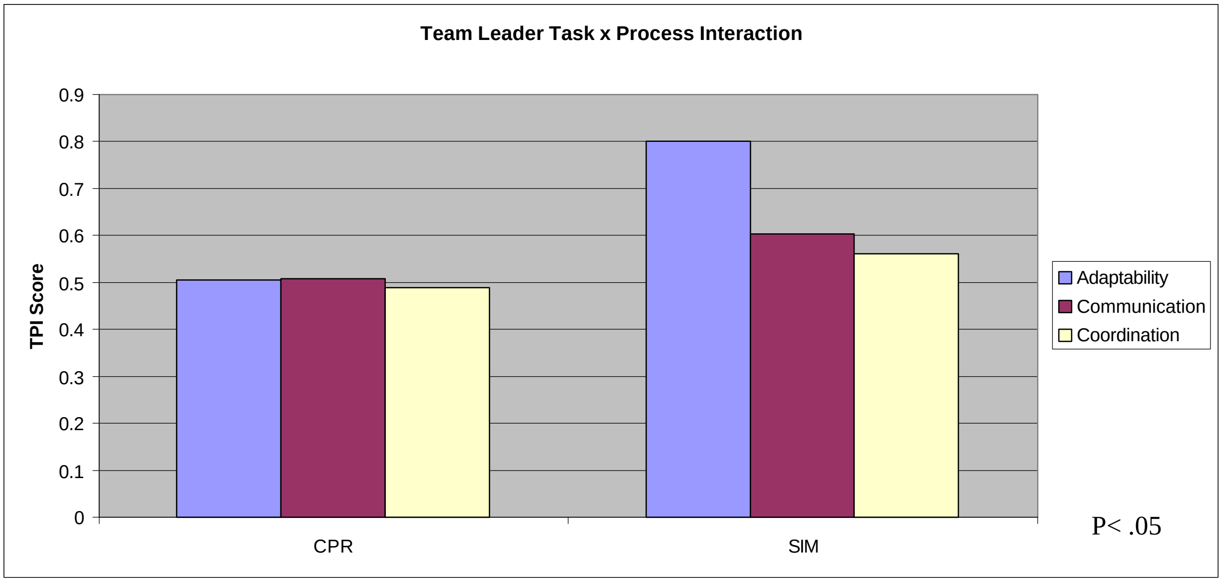


Figure 16. Team leader task x process interaction

The results for the team member performance ANOVA are shown in Table 18.

Table 18. Analysis of Variance for Team Member Performance

Source	DF	SS	MS	F	P
Task	1	0.09809	0.09809	118.00	0.000*
Process	2	0.11254	0.05627	12.03	0.004*
MOPP	1	0.01067	0.01067	0.21	0.672
Team	4	0.48622	0.12156	7.90	0.007*
Task*Process	2	0.34589	0.17294	10.11	0.006*
Task*MOPP	1	0.00091	.00091	0.06	0.825
Task*Team	4	0.00333	0.00083	0.05	0.993
Process*MOPP	2	0.00031	0.00015	0.02	0.976
Process*Team	8	0.03741	0.00468	0.30	0.944
MOPP*Team	4	0.20521	0.05130	3.34	0.069
Task*Process*MOPP	2	0.00601	0.00301	0.20	0.826
Task*Process*Team	8	0.13691	0.01711	1.11	0.442
Task*MOPP*Team	4	0.06571	0.01643	1.07	0.432
Process*MOPP*Team	8	0.04991	0.00624	0.41	0.888
Error	8	0.12302	0.01538		
Total	59	1.68213			

* indicates significance at ($p < 0.05$)

Results for the team member ANOVA indicated significance for the same effects and interaction as the team leader ANOVA-- Task, Process, and Team main effects as well as the Task x Process interaction effect. Again, hypothesis tests were conducted to isolate the main effects and interaction effect (See Appendix E for all t-test results). Figures 17 shows the task main effect.

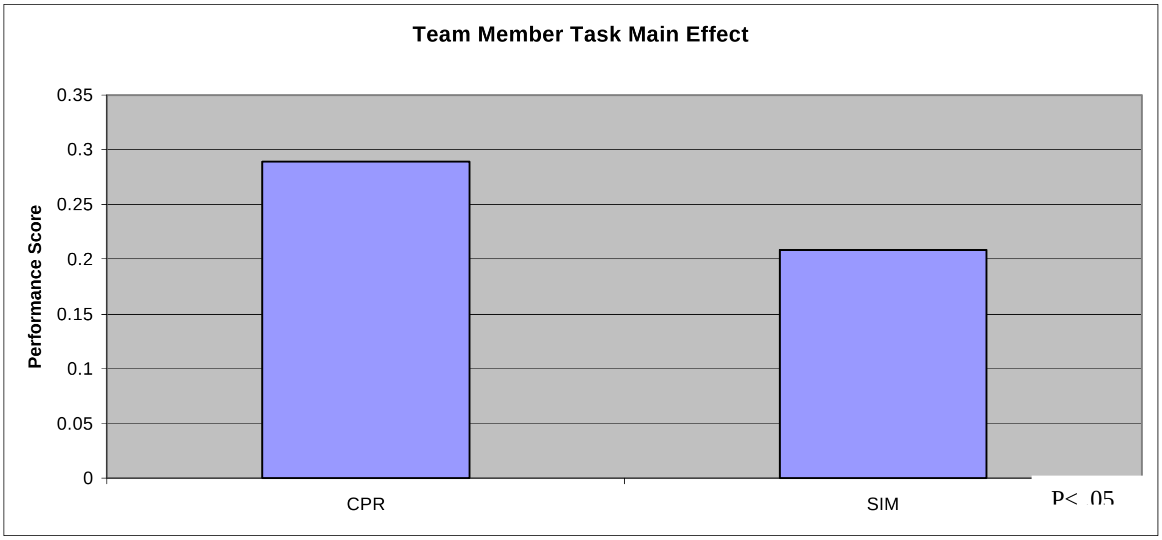
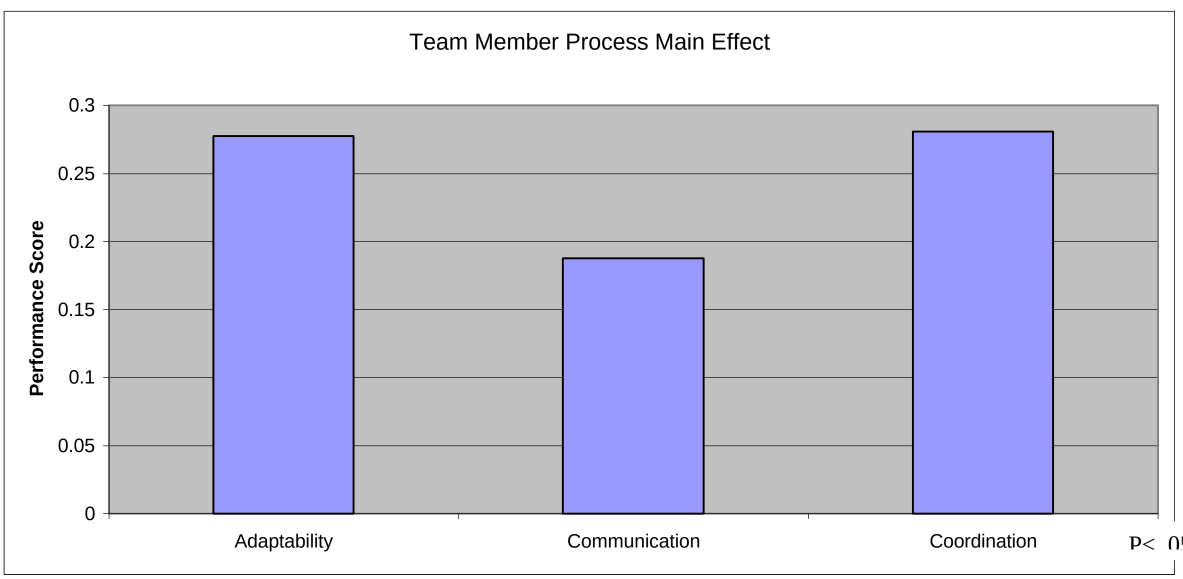


Figure 17. Team member performance as a function of task

The mean team member performance score during CPR was .289. The mean score during SIM was .208. The task main effect was shown by a significantly higher team member



performance score during CPR tasks (p = .025). Figure 18 shows the process main effect.

Figure 18. Team member performance as a function of team process

The mean performance score was .278 for adaptability, .188 for communication, and .281 for coordination. The process main effect indicated that communication performance was significantly higher than coordination performance. Figure 19 shows the mean team member performance scores.

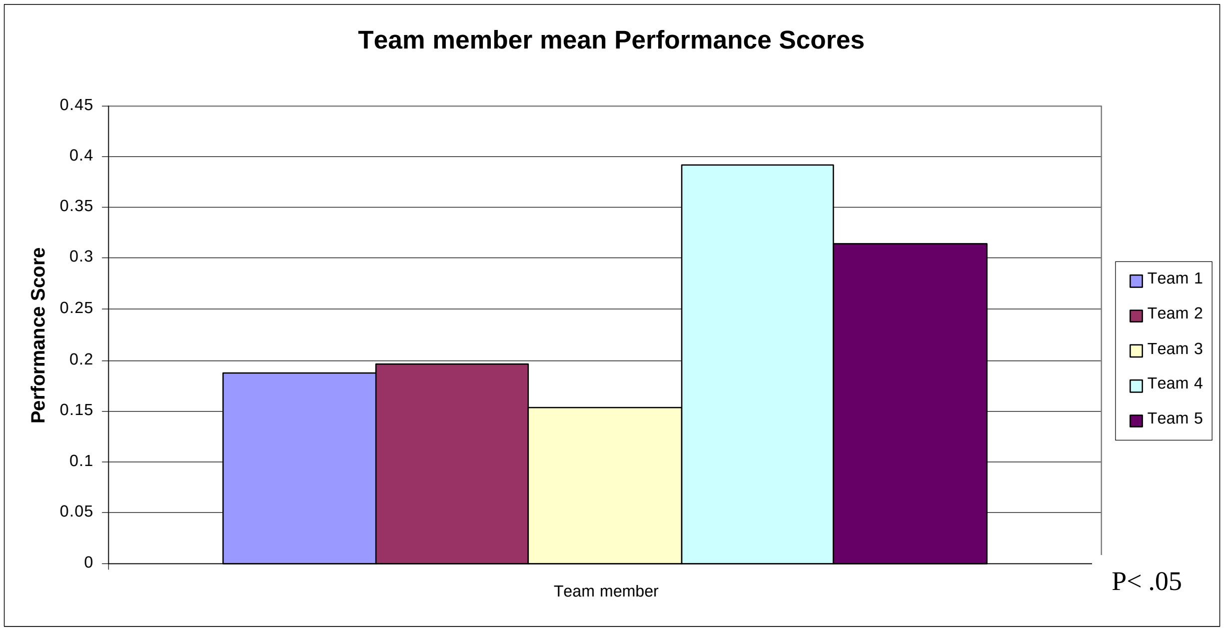


Figure 19. Team performance as a function of team

The highest team member performance score was for Team 4 followed in decreasing order by Team 5, 2, 1, and 3. Team member performance scores were not significantly different between Teams 4 and 5; however, the scores were significantly higher than Teams 1, 2, and 3. Scores for Teams 1, 2, and 3 were not significantly different from each other. Figure 20 shows the task x process interaction for team member performance.

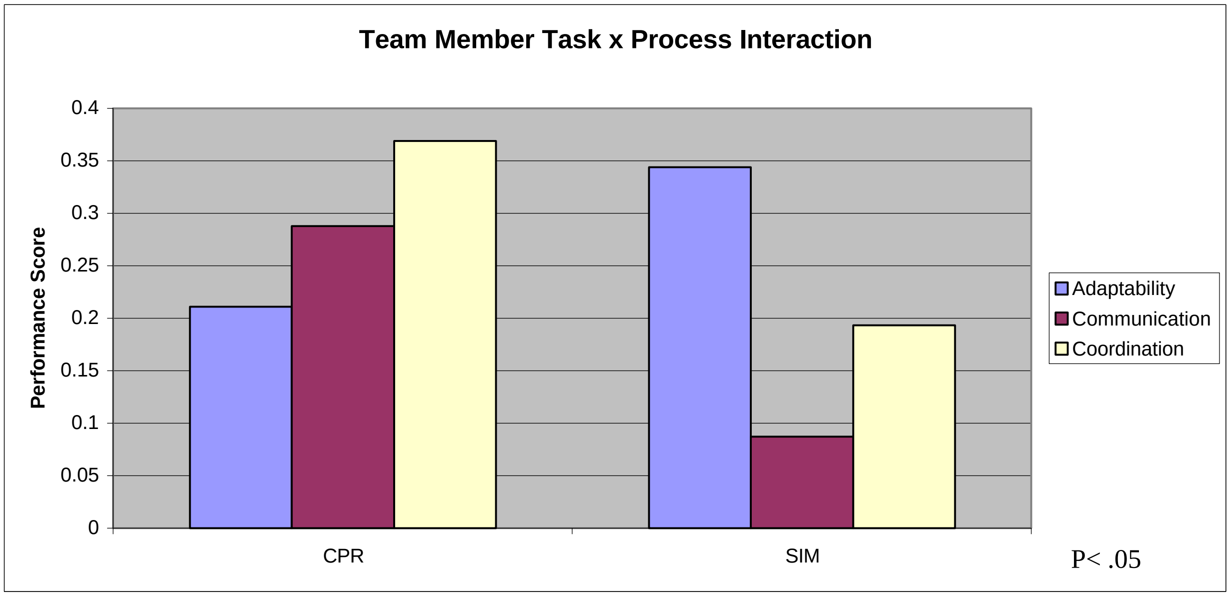


Figure 18. Team member task x process interaction

The Task x Process interaction for CPR tasks showed significantly higher coordination performance than either adaptability (p = .02) or communication (p = .003) performance. For SIM tasks, adaptability performance scores were significantly higher than communication (p = .00004) and coordination (p = .002) performance scores. Coordination scores were also significantly higher than communication scores (p = .002).

Task Completion Time

An ANOVA was conducted to determine if MOPP level affected the completion times for each task. The results are shown in Table 19.

Table 19. Analysis of Variance for Completion Time

Source	DF	SS	MS	F	P
MOPP	1	8.8942	8.8942	10.23	0.033*
Task	1	96.7265	96.7265	48.81	0.002*
Team	4	0.5072	0.1268	0.29	0.871
MOPP*Task	1	3.0441	3.0441	6.95	0.058
MOPP*Team	4	3.4773	0.8693	1.99	0.261
Task*Team	4	7.9272	1.9818	4.53	0.086
Error	4	1.7517	0.4379		
Total	19	122.3282			

* indicates significance at (p< 0.05)

The ANOVA indicated significance for the Task and MOPP main effects. Figures 21 and 22 show the task completion time as a function of MOPP level and task, respectively.

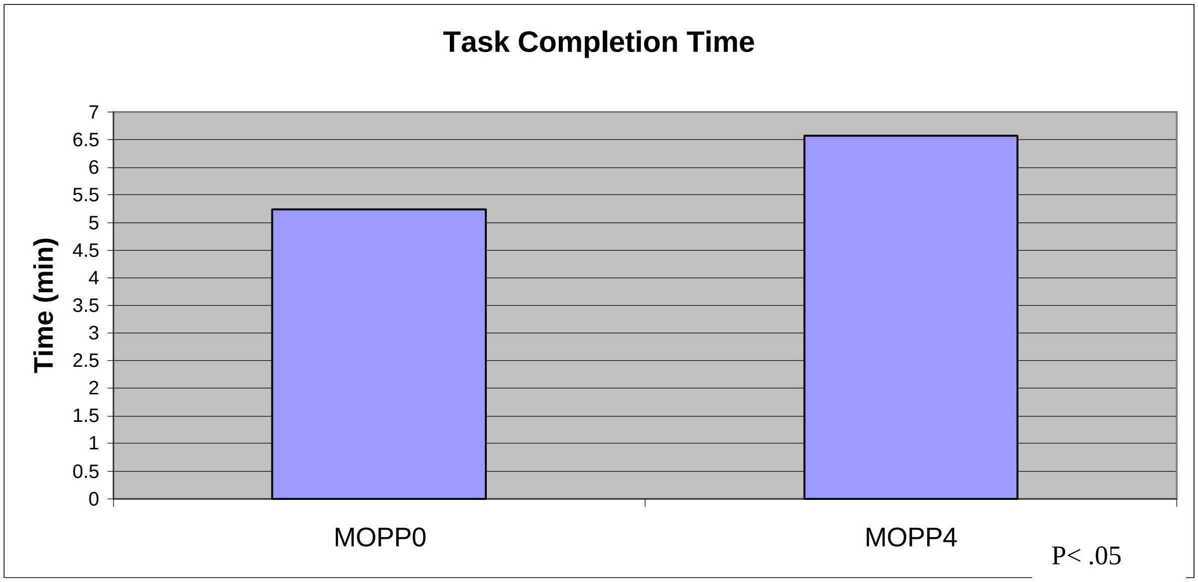


Figure 21. Task completion time as a function of MOPP level

The mean completion time in MOPP 0 was 5.24 minutes compared to 6.57 minutes in MOPP 4.

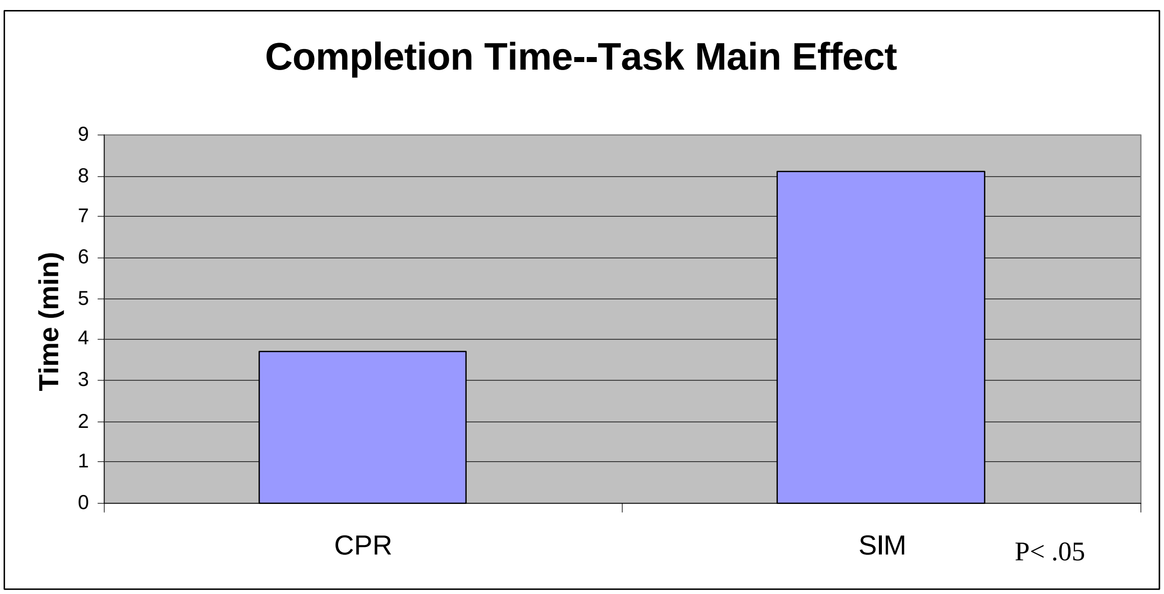


Figure 22. Task completion time as a function of task

The mean completion time for CPR tasks was 3.71minutes compared to 8.11 minutes for SIM tasks.

Hypothesis tests were conducted to isolate the main effects. The results of the paired t-test for the MOPP main effect were as follows:

t-Test: Paired Two Sample for Means

	M0 time	*M4 time*
Mean	5.24297	6.5767
Variance	4.03582352	8.567959789
Observations	10	10
Pearson Correlation	0.915359604	
Hypothesized Mean Difference	0	
df	9	
t Stat	-3.110564631	
P(T<=t) one-tail	0.006253733	
t Critical one-tail	1.833113856	
P(T<=t) two-tail	0.012507465	
t Critical two-tail	2.262158887	

H_0 was rejected at p = .006. It was concluded based on the means that MOPP 4 completion times were significantly longer than MOPP 0 completion times.

The result of the t-test for the Task main effect was as follows:

t-Test: Paired Two Sample for Means

	CPR time	*SIM time*
Mean	3.71067	8.109
Variance	0.440444933	2.404187778
Observations	10	10
Pearson Correlation	0.008404284	
Hypothesized Mean Difference	0	
df	9	
t Stat	-8.271782199	
P(T<=t) one-tail	8.4665E-06	
t Critical one-tail	1.833113856	
P(T<=t) two-tail	1.6933E-05	
t Critical two-tail	2.262158887	

H_0 was rejected at p = .000. From the mean completion times, it was concluded that completion time for the SIM task was significantly longer than completion time for CPR. The average completion time for all tasks increased 25.4% when teams were wearing MOPP 4. Specifically, the average completion time for CPR tasks increased 16.1% when teams were wearing MOPP 4 and the average completion time for SIM tasks increased 29.9% when teams were wearing MOPP 4 as compared to MOPP 0.

Errors

Both the total number of errors committed and a weighted total error score were calculated for each team. The weighted total error score was determined for each task by the following equation:

$$\sum_{i=0}^{N} (\text{Error x Severity})$$

The severity of each error was rated on a scale from 1 to 10 (1= not severe and 10=extremely severe) as determined by the Captain of the Virginia Tech Rescue Squad. Appendix F contains the breakdown of errors and error severity for each team during all four tasks.

An ANOVA was conducted to determine if MOPP level affected the number of errors or the severity of errors committed for each task. The results for weighted error (error severity) are shown in Table 20.

Table 20. Analysis of Variance for Weighted Error

Source	DF	SS	MS	F	P
Task	1	12.80	12.80	0.43	0.548
MOPP	1	20.00	20.00	0.29	0.618
Team	4	300.20	75.05	0.94	0.524
Task*MOPP	1	1.80	1.80	0.02	0.888
Task*Team	4	119.20	29.80	0.37	0.819
MOPP*Team	4	274.00	68.50	0.86	0.558
Error	4	320.20	80.05		
Total	19	1048.20			

The ANOVA indicated no significant effects for weighted error. Table 21 shows the results for the ANOVA conducted on the number of errors committed during each task.

Table 21. Analysis of Variance for Number of Errors

Source	DF	SS	MS	F	P
Task	1	7.2000	7.2000	2.55	0.186
MOPP	1	0.8000	0.8000	0.48	0.528
Team	4	8.3000	2.0750	6.38	0.050*
Task*MOPP	1	0.2000	0.2000	0.62	0.477
Task*Team	4	11.3000	2.8250	8.69	0.030*
MOPP*Team	4	6.7000	1.6750	5.15	0.071
Error	4	1.3000	0.3250		
Total	19	35.8000			

The ANOVA indicated significance for the Team main effect and the Task x Team interaction. Hypothesis tests were conducted to isolate the main effect and interaction effect. (See Appendix E for results) Figure 23 shows the team main effect for number of errors. Figure 24 shows the average number of errors per team for both CPR and SIM tasks.

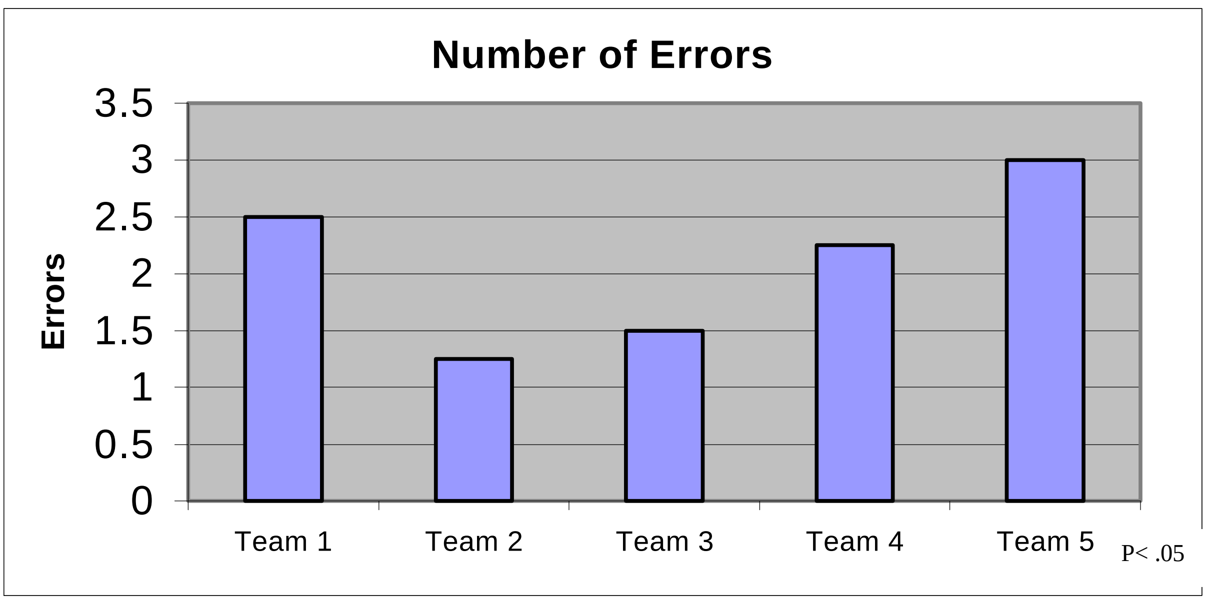


Figure 23. Number of errors as a function of team

Although the ANOVA indicated significance, t-tests did not indicate a significant difference between teams when errors were averaged across both tasks.

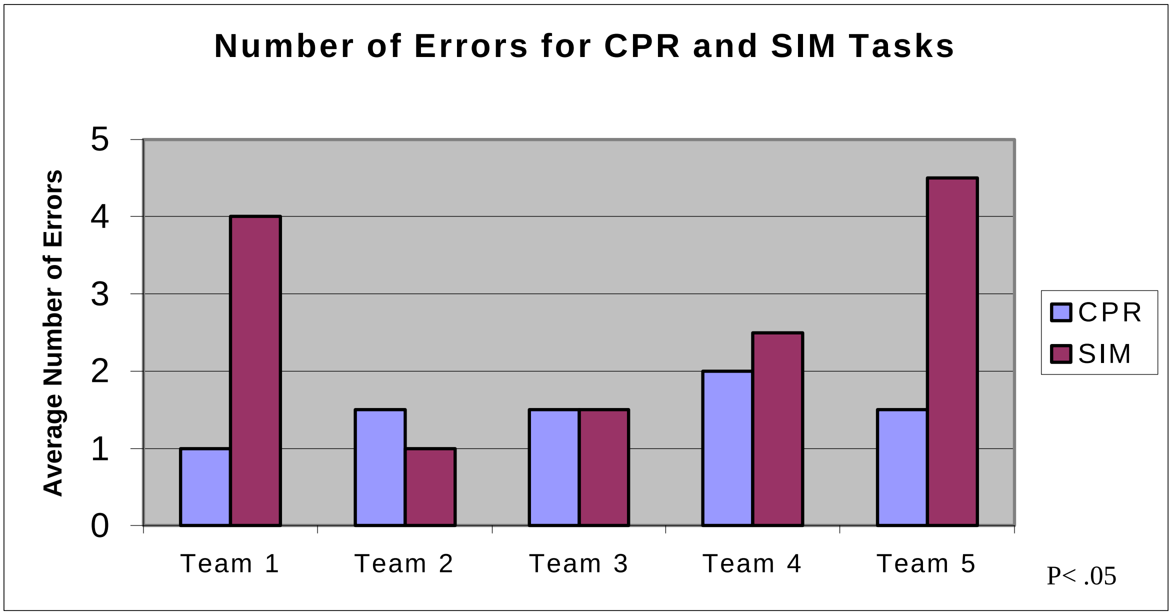


Figure 24. Number of errors (task x team interaction)

Although the graph appears to indicate a difference between the number of errors committed during CPR vs. SIM for Teams 1 and 5, there was no significant difference. Due to large variances, t-tests indicated that the only significant effect was that Team 5 had more errors than Team 2 during the SIM tasks ($p = .045$).

Workload

Each team member rated their workload using the NASA TLX subjective workload assessment tool after each task. Figure 25 shows a comparison of average workload ratings for MOPP 0 vs. MOPP 4. The average workload rating for CPR was 33.5 in MOPP 0 and 44.6 in MOPP 4. That represented an 33.1% increase when teams were wearing MOPP 4. The average workload rating for SIM tasks was 34.4 in MOPP 0 and 55.7 in MOPP 4. That resulted in an increase of 61.9% when teams were wearing MOPP 4.

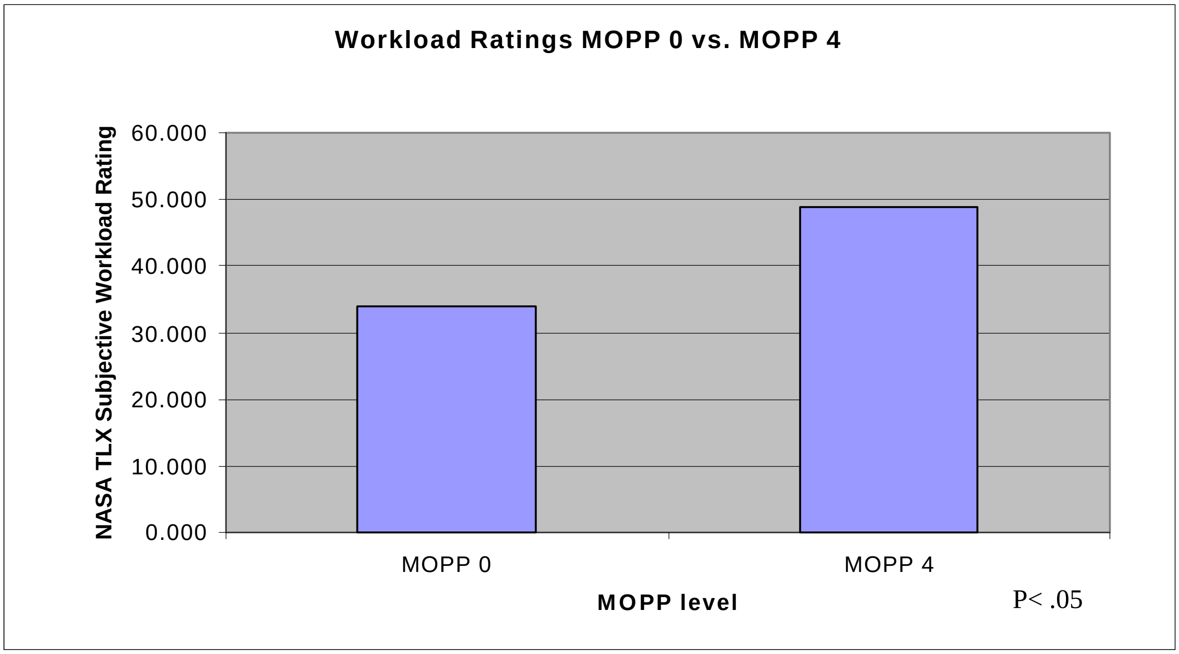


Figure 25. Subjective Workload Ratings

An ANOVA was performed to determine if there was a significant difference in subjective workload ratings for MOPP 0 as compared to MOPP 4 and for team leaders as compared to team members for both tasks. The results are shown in Table 22.

Table 22. Analysis of Variance for Workload

Source	DF	SS	MS	F	P
MOPP level	1	2195.3	2195.3	9.71	0.004*
Task	1	222.4	222.4	0.98	0.329
Role	1	350.0	350.0	1.55	0.222
MOPP lev*Task	1	140.6	140.6	0.62	0.436
MOPP lev*Role	1	53.7	53.7	0.24	0.629
Task*Role	1	258.4	258.4	1.14	0.293
Error	33	7462.9	226.1		
Total	39	10683.4			

* indicates significance at p< .05

The ANOVA indicated that there was significance for the MOPP main effect. A paired t-test was performed to isolate the main effect. The results were as follows:

t-Test: Paired Two Sample for Means

	MOPP 0	*MOPP 4*
Mean	33.9264	50.14325
Variance	233.7801588	236.0955111
Observations	20	20
Pearson Correlation	0.141569126	
Hypothesized Mean Difference	0	
df	19	
t Stat	-3.611078415	
P(T<=t) one-tail	0.00093047	
t Critical one-tail	1.729131327	
P(T<=t) two-tail	0.001860939	
t Critical two-tail	2.093024705	

A one-tailed t-test indicated that the mean workload rating for MOPP 4 was significantly higher than the workload rating for MOPP 0.

Team Performance Indicators

In order to determine what factors were significantly correlated with team performance (as measured by team TPI score) as well as to determine the relationships between several other variables, a matrix of performance variables and their relationships were calculated using the Pearson correlation coefficient. The following variables were considered: TPI, completion time, number of errors, error severity (weighted error), average team workload rating, team leader workload rating, and team member workload rating. The results are shown in Table 23.

A correlation coefficient of r = .669 was significant at the α = .05 level (Edwards, 1967). There was a significant positive correlation between team coordination scores and overall TPI scores (r = .912); a significant correlation between team communication scores and overall TPI scores (r = .759); and a significant correlation between team communication scores and overall TPI scores (r = .759). There was a significant positive correlation between team adaptability scores and the completion time (r = .768). There was a significant negative correlation between team coordination scores and the number of errors committed during a task (r = -.914). And finally, there was a significant correlation between leader workload and average workload (r = .841) and between team member workload and average workload (r = .744).

Table 23. Team Performance Factor Correlation

	TPI	Time	# Errors	Wt. Error	TPI-adapt	TPI-comm	TPI-coord	Avg workload	Leader workload
Time	-.216								
# Errors	-.780	.474							
Wt. Error	-.535	.019	.400						
TPI-adapt	.073	.768	.286	-.341					
TPI-comm	.759	-.028	-.463	-.511	.240				
TPI-coord	.912	-.364	-.914	-.561	-.128	.663			
Avg. Work	-.048	.17	.030	-.108	.072	.055	-.023		
Leader work	.151	.034	-.200	-.068	-.067	.061	.214	.841	
Member work	-.272	.260	.301	-.108	.210	.023	-.305	.744	.264

Hypothesis tests were conducted using the Fisher Z transformation of r to determine if there was a significant difference between correlation (r) values. Z-values were found in the Table VI of Z_r values in Edwards (1967). The format of the hypothesis test was as follows:

$H_0 : r_1 - r_2 = 0$
$H_a : r_1 - r_2 \neq 0$
$\alpha = 0.05$
Reject H_0 if $|Z_{observed}| > Z_{tabled}$

Hypothesis test calculations are shown in Appendix E. Results of the hypothesis tests indicated that there was no significant difference between the correlation values.

Post-experiment Questionnaire

The post-experiment questionnaire was analyzed qualitatively. When asked whether MOPP 4 affected the teams' ability to adapt, communicate, and coordinate actions, the average response fell between somewhat less able to perform and no effect on a scale of 1 to 5 (1 = much less able to perform and 5 = much more able to perform). The mean response to the question "Did wearing MOPP during the rescue affect your ability to adapt or respond to changing events that occurred throughout the rescue?" was 2.4 (SD = .84). The mean response to the question "Did wearing MOPP during the rescue affect your ability to communicate during the rescue?" was 2.1 (SD = .57). The mean response to the question "Did wearing MOPP during the rescue affect your ability to coordinate as a team during the rescue?" was 2.6 (SD = .70)

Subjects were asked a series of questions adapted from Morgan, et al., (1986) regarding interactions between team members. Responses were on a scale from 1 to 5 (1=strongly disagree and 5 = strongly agree). Subjects generally agreed that communications were always clear between team members (mean = 3.8), that success in the job depended heavily upon the actions of the other team member (mean = 3.9), and that they completely understood how their position fit in with the work of other members on the team (mean = 4.0).

When asked to rate their individual performance, their team member's performance, and their team's performance on a scale from 1 to 5 (1 = very poor, 5 = very good), subjects generally rated all three performance categories as good. The mean scores for individual, team member, and team performance were 3.7, 3.9, and 3.9, respectively.

When participants were asked open-ended questions about how they overcame or ignored any adverse effects of the MOPP, the most frequent responses included focusing on the patient or task and speaking louder. The most frequent response to the question "What was the most difficult part of the experiment?" included ill-fitting gear and difficulty speaking to partner. Suggestions for improving MOPP included providing better ventilation, designing the mask with a continuous faceshield, adding inter-helmet (mask) communication devices such as electronic voice ports.

Chapter 5. Discussion

This study tested three hypotheses with respect to the effect of MOPP level on team process performance and on team performance outcomes. They were as follows:

1. Team process performance will be degraded when teams are wearing MOPP 4.

2. Task completion time will increase when teams are wearing MOPP 4.

3. The number of errors will increase when teams are wearing MOPP 4.

Hypothesis 2 was supported by the results; hypotheses 1 and 3 were not supported. Although team performance outcomes were degraded by MOPP 4 (i.e., the task completion time increased significantly when teams were wearing MOPP 4), there was no statistical evidence to support the hypothesis that team process performance was degraded by MOPP 4. To further explain the results from this study and to expand on the analysis of the validity of the hypotheses, the following questions will be discussed:

1. What are the effects of MOPP on team process behaviors when team members are wearing MOPP 4?

2. How does team process performance vary for different taxons of tasks?

3. What, if any, is there a relationship between the role assigned (e.g. team member vs. team leader) and the effects of MOPP on performance?

4. Which team performance processes are related to performance outcomes?

Team Process Performance

The results of the ANOVA for TPI scores indicated no significant difference in team process performance in MOPP 0 vs. MOPP 4. Teams were able to focus on the task at hand despite the discomfort or frustration that occurred when wearing MOPP 4 possibly due in part to the relatively short duration of the rescue tasks and the controlled climate. Teams were able to ignore any adverse effects when coordinating and communicating actions. Although many team members commented on the difficulty of communicating through the gas mask, team members simply repeated the communication or spoke loudly enough that the difficulty was overcome. If team members were performing the task in hot or humid conditions or for a longer period of time, it is possible that communication and coordination would suffer as the teams became more uncomfortable and frustrated with the equipment.

Across all four tasks, adaptability performance scores were significantly higher than communication scores. Teams were better able to adapt to unexpected situations such as using two people to perform standing backboarding than they were able to communicate. A possible explanation for the lower communication score is the frequent occurrence of non-verbal communication between team members. For members of a team who are highly trained at specific tasks and are cross-trained to perform any role on the team, the standard procedures are followed so often that team members automatically perform tasks without needing to speak or communicate. Their ability to adapt is a function of training rather than their ability to communicate with each other. In addition, in rescue tasks where adaptation to unexpected events is critical to the survival of a patient, verbal communication can slow down the process and ultimately lead to complications in performing the rescue. The nature of emergency care, in general, requires that each team member know his or her specific role without being told what to do in every situation. Another consideration involves the fact that the EMT teams were not pre-existing. Perhaps they would have communicated more effectively had the members previously worked together on a regular basis.

Results from the ANOVA also indicated that team process performance was a function of the task being performed. During CPR tasks coordination performance was better than communication performance. The CPR tasks in this study required coordination for timing compressions and breathing and also for responding to complications such as the victim having a seizure. In most cases, the team members communicated frequently by counting the number of compressions and verbally communicating the time that had passed. The tasks were routine enough, however, that communication was not necessary for team members to coordinate actions. Rather than speaking aloud, team members simply used nonverbal cues to provide information to one another. Physical coordination movements such as alternating compressions with rescue breathing were required to complete the task; however, teams used the minimum verbal communication necessary to successfully coordinate actions.

During SIM tasks, adaptation scores were significantly higher than both communication and coordination scores. The higher adaptation scores during SIM tasks can be explained by the requirements of the task itself and the assignment of roles prior to the task. Typically, the team member was responsible solely for holding the victim's head stationary, Because that job function was critical, the team leader performed most of the other tasks by himself without the assistance of the team member. He adapted to events without communicating to or coordinating with the team member because the member was preoccupied. Moreover, all teams adapted well to backboarding the victim with only two team members and to removing the object which blocked the victim's airway. Teams used only the amount of communication and coordination necessary to successfully adapt to unexpected situations.

Team Leader vs. Team Member Performance

MOPP level had no effect on either team leader or team member performance. The ANOVAs for assessing team leader and team member performance indicated that performance differed significantly by task, team, and process. There was also an interaction between task and process. It was interesting to note that team leader performance scores were significantly higher during the SIM task than during CPR tasks while the converse was true for team member performance scores. Team member scores were significantly higher during CPR tasks than during SIM tasks. During the backboarding tasks, most team leaders delegated the task of maintaining the posture of the spine to the team member. Team leaders made the decisions, coordinated the team's actions and communicated with the victim and the team member. Team members contributed to problem-solving; however, their primary role was to follow instructions. During CPR, however, the task required more communication and coordination between the team members. The team leader and team member functioned interdependently, which allowed for more interaction rather than delegation. The result was higher performance scores for leaders when the situation demanded that they take control and higher scores for team members when the situation demanded interaction and a more equal role in the rescue.

As Figures 6 and 7 indicated, both team leader and team member scores for Teams 1, 2, and 3 differed significantly from Teams 4 and 5. The significantly lower team leader scores for Teams 4 and 5 were compensated for by significantly higher team member scores than Teams 1, 2, and 3. Team members compensated for the inadequacies in the team leader's performance by contributing higher performance than those teams whose leader's had high performance scores. This phenomenon was further supported by the results of the overall team performance ANOVA which indicated no difference in team performance between teams.

The Process main effect indicated that team leaders had significantly higher adaptation performance scores than either communication or coordination. Team members had significantly higher communication performance scores than coordination scores. The results of the hypothesis tests provided an indication of how the participation within the team was a function of the role assigned. Team leaders had higher scores for adapting to unexpected or unknown situations than for communicating and coordinating actions. Team leaders, in general, tended analyze the rescue environment and scenario and then decide on a course of action. Although some consultation with team members occurred, team leaders were more likely to adapt to the event on their own than to communicate or coordinate with the team member.

Team members had higher scores for communicating than coordinating. The primary role of the team member was to keep the team leader informed on the victim's condition, to communicate task updates, and to contribute advice to team leaders. Because coordination of tasks was primarily the leader's function rather than the team member's function, coordination performance scores were significantly lower.

The Task x Process interaction results can be explained as a function of the requirements of the task. For the same reasons provided during the team process performance discussion, team leaders and team members utilized the team processes which were required for task completion.

Team Performance as a Function of Task Taxon

As stated in the results section, team performance scores during GML tasks were significantly higher than during all other taxons of tasks; performance scores during GMH, and FMD tasks were significantly higher than during cognitive, communication, and visual tasks. Performance of manual tasks such as moving the victim (GMH), giving compressions (GML), and strapping the victim onto the backboard (FMD), for example, were required by the standard EMS procedures for rescuing a victim. Most teams were able to accomplish these tasks as a result of their previous training and rescue experience. Performance during tasks such as cognitive decision-making and communication, however, were more team process-oriented and allowed for more performance variation while still accomplishing the end goal. Teams may not have made good decisions or communicated well, but they were still required to perform the manual tasks required by standard rescue procedures.

The amount of communication or coordination necessary to accomplish the task may have also been dependent upon the team members' previous experience working with each other. A communication pattern or coordination skills may not have been established; however, they were trained to be competent at all required physical tasks. The results was higher performance during manual tasks than during tasks that required team processes.

Task Completion Time

Task completion time increased significantly when teams were wearing MOPP 4. Completion time increased an average of 25.4% for all tasks. Completion time increased 16.1% during CPR tasks and 29.9% during SIM tasks. Several factors may have led to increased task completion time. Teams often had to repeat information when communicating which added to the task completion time. Teams adjusted equipment such as the gas mask and gloves throughout the tasks which took time away from completing the task. SIM tasks were more affected by MOPP 4 than CPR tasks due to the nature of the task. Teams were required to fit straps into small holes in the backboard and to use tape which was difficult with the gloves. CPR completion time was significantly shorter than SIM task completion time due to the design of the scenarios.

Errors

MOPP did not have a statistically significant effect on either the number of errors or the severity of errors committed. The insignificant results may be attributed to high levels of training and the simplicity of the tasks. Awareness that teams were being evaluated for proficiency may have resulted in performance effects during all four tasks. And finally, the length of experience of the team leader may have prevented errors because most of the decision-making was performed by the team leader.

Team Performance Indicators

In order to determine which team performance processes were related to team performance outcomes, the correlation between team process performance scores and outcome data such as overall TPI, completion time, and errors were calculated. The significant correlation between the team process score for coordination and overall team performance score (r = .912) indicated that a teams ability to coordinate actions was an indicator of good performance overall. There was also a significant correlation between the team process score for communication and overall team performance (r = .759). The use of non-verbal communication or a team's ability to perform tasks without communication because of extensive training could explain why the correlation was not as strong as coordination; however, high communication scores were an indicator of good overall performance. There was a significant correlation between team coordination scores and the number of errors committed (r = -.914). If teams were unable to coordinate decision-making processes or manual tasks, the result was more errors committed. The significant correlation between overall team performance scores and the number of errors committed (r = -.780) supported the converse of the above statement--as the overall performance of a team increased, the number of errors decreased. Completion time was not an indicator of team performance. From the results of this study, a generalization was made that only coordination and communication were related to team performance outcomes.

Chapter 6. Conclusion

Summary

The results of this study did not find a degradation of team process performance when teams wore MOPP 4 as opposed to MOPP 0. The subjective ratings of performance degradation on the post-experiment questionnaire supported that result by indicating that teams did not feel a strong degradation in their ability to adapt to changing situations, to communicate with each other, or to coordinate with each other. The significantly higher NASA TLX subjective workload ratings for tasks that utilized MOPP 4 indicated some increase in workload at the individual level, but the increased workload apparently did not affect a team's ability to communicate or coordinate actions. Moreover, the results of this study did not find an increase in the number of errors or severity of errors. Teams subjectively rated their overall performance as good regardless of the number of errors or error severity.

The most plausible explanation for these results is the nature of the rescue tasks and the team performance measurement technique used in this study. In order to use the TARGETS methodology, all task scenario events were scripted. A less rigidly controlled scenario might allow for a wider range of responses and interactions between team members. CPR and SIM required the teams to follow strict rescue procedures and teams were penalized with errors for deviating from the standard procedure. The levels of coordination, communication, and adaptability required to successfully perform a rescue were already built into the training regimen. It is possible that team processes were not degraded because the teams were formally trained to respond to events and each other in certain ways. Therefore, the results of this study may not generalize to tasks which have more complexity and a wider range of possible responses.

Task duration and task environment might have also impacted the results. The tasks might have been too short for team members to become sufficiently fatigued or frustrated enough to see a degradation in their ability to interact and coordinate actions. In addition, the controlled climate did not allow for team members to become overheated. If tension levels in individuals rise as a result of the increased heat experienced when wearing MOPP, their ability to interact with other team members may decrease.

The trade-off between experimental control of the tasks and generalizability to real-world tasks played a major role in the outcome of this study. The team performance measurement technique used and the resulting task scenarios limited the team's ability to interact at a level which might have produced significant results.

Design Recommendations

The purpose of chemical protective clothing is to provide a worker with a barrier between themself and a dangerous environment. To do this, the clothing and equipment must be made from certain materials and have certain characteristics. The results of this study, however, indicated a need to redesign the equipment in order to permit teams to function properly in protective clothing. Recommendations for design improvements were derived from the data and suggestions from participants.

Results from the analysis of team performance as a function of task taxon indicated that performance during cognitive, communication and visual tasks was lower than tasks requiring physical movements. Performance degradation during cognitive tasks could be the result of discomfort and frustration with the equipment. An overall feeling of discomfort due to excessive heat or claustrophobia, for example, distracts team members from the task and increases their cognitive workload. The result is lower cognitive performance ability. To counteract this effect, the weight of the material used for the overgarments should be reduced without compromising its effectiveness. Materials which “breathe” and move moisture away from the body will increase the comfort level and allow team members to focus on the task rather than their discomfort. Vision should be improved by increasing the field of view through the gasmask. This could be accomplished by utilizing one continuous visor rather than two goggles. To improve team member’s ability to communicate with one another, the gas mask must be modified. Communication could be improved by including a supplementary communication device such as a voice port within the gas mask.

Results from this study also indicated that task completion time increased when teams were wearing MOPP. Improvements to the equipment that reduce bulkiness and allow team members to move more freely in the equipment will reduce the time it takes to move themselves or other objects. Moreover, ill-fitting gloves reduced team member’s ability to perform tasks requiring manual dexterity. Providing gloves in more sizes than small, medium, and large will help reduce frustration and improve performance during fine motor tasks.

Future Research

The assessment of team process performance is critical for identifying problems and improving team training. As shown in this study, a degradation in team performance outcomes is not necessarily an indication of degradation in team processes. Therefore, in order to diagnose team performance problems, both outcomes and processes must be assessed. The methods for measuring team process performance, however, need to be improved. Future research on team performance should focus on developing team performance measurement techniques which allow for broad task scenarios, but do not rely strictly on behavioral rating systems. Event-based methodologies provide high inter-rater reliability, but restrict the responses of the teams. Behaviorally-based measurement systems, on the other hand, allow for broader task scenarios but have very low inter-rater reliability. The development of a measurement system which can bridge the gap between the two methodologies would increase the range of tasks that can be studied and improve the generalizability of the results. A possible method for bridging the gap between event-based and behaviorally-based techniques is to elicit behaviors from teams according to a script, but also provide a means for behaviorally assessing behaviors which do not strictly follow the scripts. Lastly, the applicability of team performance measurement to nominal groups should be validated to ensure that results from studies that use nominal groups can be generalized to teams.

Researchers should also consider the effects of using highly trained subjects when selecting or developing a measurement technique. As task complexity increases, measuring team performance becomes more difficult. However, using highly trained subjects to limit the variability of behaviors and improve the effectiveness of the measurement technique leads to a new set of difficulties. As team members become increasingly familiar with a particular task through training, the method for interacting and coordinating with team members becomes less noticeable to the observer. For example, team members often use nonverbal cues or even perfect the timing of a task so that communication is unnecessary. Researchers must understand that a task which requires interdependence does not necessarily result in observable coordination or communication behaviors. Highly trained teams can adapt to situations as a function of training rather than as a function of interactions with team members. Future researchers must carefully consider these trade-off between reducing behavior variability and complicating the experiment by using highly trained subjects.

Future research on the effects of MOPP on team process performance should be conducted using more complicated task scenarios. The results of this study may generalize to some military tasks such as medic operations or first aid in the field; however, more research needs to be done to validate these results in a broader range of tasks. Furthermore, the effects of chemical protective clothing, in general, on team process performance should be studied so that a variety of industries can benefit. Civilian industries can modify training for team tasks and improve team outputs. Both civilian and military personnel will benefit from improvements to equipment and improvements in team process performance improvements and changes accordingly.

References

Adams, A.S., Slocum, A.C., and Keyserling, W.M. (1994) A Model for Protective Clothing Effects on Performance. *International Journal of Clothing Science and Technology*, 6(4), 6-15.

American Red Cross. 1993. CPR for the Professional Rescuer. Boston: StayWell.

Baker, D.P. and Salas E. (1992). Principles for measuring teamwork skills. *Human Factors*, 34(4), 469-475.

Bowers, C., Salas, E., Prince, C., and Brannick, M. (1992) "Games teams play: A method for investigating team coordination and performance." Behavior Research Methods, Instruments, and Computers, 24 (4), 503-506.

Brannick, M.T., Roach, R.M., and Salas E. (1991, April). *Understanding team performance: a multimethod study*. Paper presented at the 6th Annual conference of the Society for Industrial and Organizational Psychology, St. Louis, MO.

Brannick, M.T., Prince, A., Prince, C., and Salas, E. (1995). The measurement of team process. *Human Factors* 37(3), 641-651.

Cox, A.B., Jeffers, A.E., and Mascarella, T.M. (1981) Ground crew chemical defense equipment performance test-time degradation (rep. No. ASD-TR-81-5003). Wright-Patterson Air Force Base, OH: U.S. Air Force Systems Command, Aeronautical Systems Division. (DTIC No. AD-B057 406)

Department of the Army. Handbook on the Medical Aspects of NBC Defensive Operations FM 8-9.

Department of the Army. (1982). U.S. Army Staff Officers Guidebook. (RB 101-999 T)

Draper, E.S. and Lombardi, J.J. (1986). Combined Arms in a nuclear/chemical environment force development testing and experimentation, phase I. Fort McClellan, AL: U.S. Army Chemical School. (DTIC No. AD-B101 686)

Dwyer, D.J. (1984). Team Research and team training: A state-of-the-art review. In F.A. Muckler (Ed.), *Human Factors Review*: 1984 (pp.285-323). Santa Monica, CA: Human Factors Society.

Edwards, A.L. 1967. Statistical Methods, 2nd Ed., New York: Holt, Rinehart, and Winston, Inc.

Fleishman, E.A., and Zaccaro, S.J. (1992). Toward a taxonomy of team performance functions. In R.W. Swezey and E. Salas (Eds.), *Teams: Their training and performance* (pp.31-56). Norwood, NJ: Ablex.

Fowlkes, J.E., Lane, N.E., Salas, E., and Oser, R. (1994). Improving the measurement of team performance: The TARGETS methodology. *Military Psychology*, 6, 47-61.

Franz, T.M., Prince, C., Cannon-Bowers, J.A., and Salas E. (1990). The identification of aircrew coordination skills. Proceedings of the 12th Annual Department of Defense Symposium (pp. 97-101). Springfield, VA: National Technical Information Services.

Gamble, K.M., and Johnston, A. (1999). Foal Eagle includes MOPP training for civilians. http://www.vnis.com/vetnews/army_news/army_news1999/army1999-169.txt

Gittelman, Donald H. "Selected Protective Clothing for Semiconductor Manufacture," Performance of Protective Clothing: Second Symposium, ASTM STP 989, S.Z. Mansdorf, R. Sager, and A.P. Nielsen, Eds., American Society for Testing and Materials, Philadelphia, 1988, pp. 347-355.

Glaser, R., Klaus, D.J., and Egerman, K. Increasing team proficiency through training: 2. The acquisition and extinction of a team response. (Technical Report AIR B64-5/62). American Institutes for Research, May, 1962.

Johnson, R.F. (1991) Rifle firing simulation: Effects of MOPP, heat, and medications on marksmanship. Proceedings of the Military Testing Association, 33, 530-535.

Johnson, R.F., McMenemy, D.J., and Dauphinee, D.T. (1990) Rifle Marksmanship with three types of combat clothing. Proceedings of the Human Factors Society, 34, 1529-1532.

Johnston, J.H., Cannon-Bowers, J.A., and Smith-Jentsch, K.A. (1995). Event-based performance measurement system for shipboard command teams. Proceedings of the 1st International Symposium on Command and Control Research and Technology, Washington, DC, 274-276.

McAteer, J. D. Miner's Manual: A Complete Guide to Health and Safety Prtoection on the Job. Occupational Safety and Health Law Center: Crossroads Press, January 1985.

McMahon, R. (2001). Email regarding MOPP training tasks.

Micro Analysis and Design. (no date) *Stressor Review Report: enhanced performance degradation and upgrades for improved performance research integration tool (IMPRINT).* (Contract DAAL01-95-C-0122).

Morgan, B.B., Jr., Glickman, A.S., Woodward, E.A., Blaiwes, A.S., and Salas, E. (1986). *Measurement of team behaviors in a Navy Environment* (NTSC Tech. Report TR-86-014). Orlando, FL: Naval Training Systems Center.

Morgeson, F.P., Aiman-Smith, L.D., and Campion, M.A. (1997). Implementing work teams: Recommendations from organizational behavior and development theories. In M.M. Beyerlein, D.A. Johnson, and S.T. Beyerlein (Eds.), *Advances in interdisciplinary studies of work teams,* Vol. 4, pp.1-44.

Morrissey, J.A. and Wick, C. H. (1989) "Degradation of Hawk Assault Fire Unit (AFU) Operating in a Chemical Environment." (Technical Report, BRL-TR-3057)

NASA Task Load Index (v. 1.0). Human Performance Research Group. Moffett Field, CA.

Nelson, C.N., Lefton, J.L., and Scott, D.E. "Protective Clothing Use in the Lawn Care Industry," Performance of Protective Clothing: Fourth Volume, ASTM STP 1133, James P. McBriarty and Norman W. Henry, Eds., American Society for Testing and Materials, Philadelphia, 1992.

Nieva, V.F., Fleishman, E.A. and Rieck, A. "Team Dimensions: Their identity, their measurement, and their relationships." (Final Technical report, ARI Contract DAHC 19078-C-001) Washington, D.C.: Advanced Research Resources Organization, 1978.

Paris, C. R., Salas, E. and Canon-Bowers, J. A. "Human Performance in Multi-Operator Systems." In Hancock, Peter A.; Ed, et al. Human Performance and Ergonomics. San Diego: Academic Press, Inc., 1999.

"Performance Measurement in Teams." Team Training Series. Orlando, FL: Naval Air Warfare Center Training Systems Division.

Prince, C., and Salas, E. (in press). Training research for teamwork in the military aircrew. In E. L. Wiener, B.G. Kanki, and R.L. Helmreich (Eds.), Cockpit resource management. Orlando, FL: Academic.

Rouse, W.B., Cannon-Bowers, J. A., and Salas, E. (1992). The role of mental models in team performance in complex systems. *IEEE Transactions on Systems, Man, and Cybernetics*, 22(6), 1296-1307.

Ronk, R., White, M., Linn, H. Personal Protective Equipment for Hazardous Materials Incidents: A Selection Guide. U.S. Department of Health and Human Services, October, 1984.

Salas, E., Dickinson, T.L., Converse, S.A., and Tannenbaum, S.I. (1992). Toward an understanding of team performance and training. In R. Swezey and E. Salas (Eds.), Teams training and performance (p. 3-29). Norwood, NJ: Ablex.

Salas, E., Bowers, C. A. and Cannon-Bowers, J. A. (1995) Military Team Research: 10 Years of Progress. *Military Psychology*, 7, 55-75.

Shiflett, S., Eisner, E. J., Price, S. J., and Schemmer, M. F. "The definition and measurement of small military unit team functions." US Army Research Institute for the Behavioral and Social Sciences Report, Ft. Benning Field Unit, 1985.

Stout, R., Salas, E., and Carson, R. "Individual Task Proficiency and Team Process Behavior:

What's Important for Team Functioning?" *Military Psychology*, 6(3), 177-192.

Taylor, H.L., and Orlanskey, J. The Effects of Wearing Protective Chemical Warfare Combat Clothing on Human Performance. *Aviation, Space, and Environmental Medicine*, March 1993, A1-A38.

US Department of Transportation, National Highway Traffic Safety Administration. Emergency Medical Technician: Basic National Standard Curriculum.

Wilson, J.R., and Corlett, E.N., Eds. 1998. Evaluation of human work: A practical ergonomics methodology. London: Taylor and Francis.

List of Appendices

APPENDIX A

Effectively Giving Suggestions or Criticism

	Leader	Member	External
1. Raised question about incorrect procedure used by a senior member of the team			
2. Called attention to a mistake made by another member without being negative			
3. Asked if the procedure or information was correct when he wasn't sure			
4. Suggested to another member that he recheck his work so that he could find his own mistake			
5. Member silently pointed to a mistake made by another member rather than announcing the mistake			

Ineffectively Giving Suggestions or Criticism

	Leader	Member	External
1. Ridiculed another member who had made a mistake			
2. Raised his voice when correcting another member			
3. Noticed a mistake and did not mention it			

Effective Cooperation

	Leader	Member	External
1. Checked with other team members when uncertain about what to do next			
2. Helped another member who was having difficulty with a task			
3. Prompted another member on what he had to do next			
4. Gave suggestions on how to do a task			
5. Member who needed assistance asked for help			
6. To help another member, performed a task that was not part of his job			
7. Wrote down notes for another team member on the performance of the latter's job			

Ineffective Cooperation

	Leader	Member	External
1. Indicated that he knows his job and shouldn't have o worry about someone else's job			
2. Failed to assist another member who was having difficulty and let him fail			
3. Member became overloaded and failed to ask for assistance			
4. Tried to push another member out of the way and do his job for him			
5. Was uncertain what to do next and failed to ask for help			

Effective Acceptance of Suggestions or Criticism

	Leader	Member	External
1. Asked what he had done wrong when told that he had made a mistake			
2. Asked other team members to tell him if he made an error			
3. Thanked another member for catching his mistake			

Ineffective Acceptance of Suggestions or Criticism

	Leader	Member	External
1. Told other members to worry about their own jobs and let him alone			
2. Argued with another member who said he had made a mistake			

Effective Communication

	Leader	Member	External
1. Communicated information to another member in the proper order			
2. Used the proper terminology when communicating information			
3. Spoke loudly and distinctly when communicating information			
4. Asked for specific clarification on a communication that was unclear			

Ineffective Communication

	Leader	Member	External
1. Lowered his voice and mumbled when communicating information to other team members			
2. Communicated information out of order			
3. Added his own comments to the prescribed commands, thereby wasting time			
4. Ignored information from another member who had previously made errors			
5. Gave a different interpretation to information provided by another member because of errors previously made by that member			
6. Failed to ask for clarification on a communication that was unclear			
7. Members were talking among themselves and missed a communication			

Effective Team Spirit and Morale

	Leader	Member	External
1. Made comments like, “we’re going to get it right this time.”			
2. Patted another member on the back			
3. Stood next to another member when the latter had a difficult task to perform			
4. Discussed ways of improving team performance			
5. Made positive comments about the team			
6. Praised another member for doing well on a task			
7. Consoled another member who made a mistake			
8. Made a joke to lighten the tension			
9. Made positive statements about the training			

Ineffective Team Spirit and Morale

	Leader	Member	External
1. Ignored a member who is not liked			
2. Formed subgroups or cliques			
3. Said something like “this team isn’t worth anything” or “this team isn’t going to make it”			
4. Argued among themselves			
5. Blamed each other for the failure of the team on an exercise			
6. While waiting for information from another member, began to harass the other member			
7. Made negative comments about another member’s performance			
8. Made negative comments about the value of the training			

Effective Adaptability

	Leader	Member	External
1. Member was able to adapt to information provided in the wrong order and made sure that he had all of the necessary information			
2. Performed a task outside of his job because the team needed to have the work done			
3. Provided suggestions on the best way to locate an error			
4. Changed the way he performed a task when asked to do so			

Ineffective Adaptability

	Leader	Member	External
1. Member was unable to adapt to information provided out of order and missed necessary information			
2. Tried to get out of doing a task that was not part of his job			
3. Refused to change the way he did a task even though he was doing it wrong			

Effective Coordination

	Leader	Member	External
1. When he finished one task, began working on another task			
2. Required information from more than one person			
3. Provided information that was needed before being asked for it			
4. Was ready with information when other members needed it			
5. Provided direction on what the members had to do next			
6. Attempted to determine the cause of discrepant information before going on			
7. When not busy with his job, watched what the other members of the team were doing			

Ineffective Coordination

	Leader	Member	External
1. Was not ready with information when another member needed it			
2. Indicated that he was finished with a task before he really was so that he could beat the clock			
3. When serving as a backup for another member, confirmed information without checking it			
4. failed to provide information unless asked			

APPENDIX B

CPR 1			
Task Taxon	**Team Process**	**TARGET**	**HIT (L/M)**
visual		visually scan room for unsafe conditions	
cognitive	coord	determine if scene is okay	
communication	comm	communicate scene is ok or indicate potential problems	
visual		visually scan room for victim	
cognitive	coord	determine who will perform tasks	
communication	comm	verbally designate tasks	
visual		Look from head to toe for severe bleeding **[no severe bleeding]**	
cognitive	coord	Determine if there is severe bleeding	
communication	comm	communicate there is no severe bleeding	
FMD		Tap or gently shake person	
communication		Shout “are you ok?” or other appropriate question **[no response]**	
communication	comm	Indicate to team member that there is no response	
FMD		Open airway (tilt head back and lift chin)	
FMC		Look, listen, and feel for 5 seconds **[not breathing]**	
FMD		Position victim onto back (if necessary)	
FMC		Look, listen, and feel for 5 seconds **[not breathing]**	
cognitive	coord	Determine if victim is breathing	
communication	comm	Indicate to team member that victim is not breathing	
FMD	adapt	Give 2 slow breaths with BVM	
visual		Watch chest to see that breaths go in **[breaths go in]**	
visual		Locate adam’s apple	
FMD		Slide fingers into groove on neck	
FMC		Feel for pulse for 5 to 10 seconds **[no pulse]**	
cognitive	coord	Determine if there is a pulse	
visual/FMD	coord	Locate hand position while R1 checks pulse	
communication/cognitive	comm	Say “no pulse, begin CPR”	
	adapt		
GML	coord	Give compressions when R1 says “begin CPR”	
communication	comm	Count out loud “one and two and three and four and five”	
	coord	Stop compressions and allow R1 to ventilate	
FMD		Give 1 slow breath with BVM	
GML	coord	Resume compressions	
GML/FMD	coord	Repeat cycles of 5 compressions and 1 breath for 1 minute	
	comm		
cognitive	coord	Determine that it is time to check victim's pulse	
communication	comm	Say “pulse check”	

visual		Locate adam's apple	
FMD		Slide fingers into groove on neck	
FMC		Feel for pulse for 5 to 10 seconds **[no breath, has pulse]**	
cognitive	coord	Determine if victim has a pulse	
visual/FMD	coord	Locate hand position while R1 checks pulse	
cognitive/communication	comm	Say "has pulse, continue rescue breathing"	
	adapt		
FMD		Give 1 slow breath with BVM	
communication	comm	Count out loud "one and two and three…"	
FMD/communication	coord	Repeat breathing and counting	
cognitive	coord	Determine that victim is having a seizure	
communication	adapt	indicate to team member to stop rescue breathing	
	comm		
	adapt	Stop rescue breathing	
	coord		
cognitive	coord	Determine that rescuers should move away and clear way objects	
	adapt		
communication	comm	communicate to team member to move away and clear away objects	
	adapt	Allow victim to seize [25-30 seconds]	
cognitive/visual	coord	Determine victim has stopped seizing	
communication	comm	Indicate to team member to begin assessing victim	
	adapt		
FMD		Open airway (tilt head back and lift chin)	
FMC		Look, listen, and feel for 5 seconds **[not breathing]**	
FMD		Position victim onto back (if necessary)	
FMC		Look, listen, and feel for 5 seconds **[not breathing]**	
cognitive	coord	Determine if victim is breathing	
communication	comm	Indicate to team member that victim is not breathing	
FMD	adapt	Give 2 slow breaths with BVM	
visual		Watch chest to see that breaths go in **[breaths go in]**	
visual		Locate adam's apple	
FMD		Slide fingers into groove on neck	
FMC		Feel for pulse for 5 to 10 seconds **[no pulse]**	
cognitive	coord	Determine if there is a pulse	
visual/FMD	coord	Locate hand position while R1 checks pulse	
communication/cognitive	comm	Say "no pulse, begin CPR"	
	adapt		
GML	coord	Give compressions when R1 says "begin CPR"	
communication	comm	Count out loud "one and two and three and four and five"	
	coord	Stop compressions and allow R1 to ventilate	
FMD		Give 1 slow breath with BVM	
GML	coord	Resume compressions	

GML/FMD	coord	Repeat cycles of 5 compressions and 1 breath for 1 minute	
	comm		
cognitive	coord	Determine that it is time to check victim's pulse	
communication	comm	Say “pulse check”	
visual		Locate adam’s apple	
FMD		Slide fingers into groove on neck	
FMC		Feel for pulse for 5 to 10 seconds **[no breath, no pulse]**	
cognitive	coord	Determine if victim has a pulse	
FMD	coord	Locate hand position while R1 checks pulse	
cognitive/communication	comm	Say “no pulse, continue CPR”	
	adapt		
GML	coord	Give compressions when R1 says “begin CPR”	
communication	comm	Count out loud “one and two and three and four and five”	
	coord	Stop compressions and allow R1 to ventilate	
FMD		Give 1 slow breath with BVM	
GML	coord	Resume compressions	
GML/FMD	coord	Repeat cycles of 5 compressions and 1 breath for 1 minute	
	comm		
communication	comm	Say “pulse check”	
visual		Locate adam’s apple	
FMD		Slide fingers into groove on neck	
FMC		Feel for pulse for 5 to 10 seconds **[victim is breathing and has pulse]**	
cognitive	coord	Determine if victim has a pulse	
FMD visual	coord	Locate hand position while R1 checks pulse	
communication		Ask "are you ok?" or other appropriate question	

CPR2

Task Taxon	**Team Process**	**TARGET**	**HIT (L/M)**
visual		visually scan room for unsafe conditions	
cognitive	coord	determine if scene is okay	
communication	comm	communicate scene is ok or indicate potential problems	
visual		visually scan room for victim	
cognitive	adapt	determine victim needs to be moved to floor	
	coord		
communication	comm	communicate need to move victim to floor	
cognitive	adapt	determine clutter needs to be moved	
	coord		
communication	comm	communicate need to clear away clutter	
cognitive	coord	determine who will clear away clutter	
communication	comm	communicate who will clear clutter	
GML		clear away clutter	
communication	comm	assign tasks for moving victim	
cognitive	coord		
GMH	coord	move victim to floor	

cognitive	coord	determine who will perform tasks	
communication	comm	verbally designate tasks	
visual		Look from head to toe for severe bleeding **[no severe bleeding]**	
cognitive	coord	Determine if there is severe bleeding	
communication	comm	communicate there is no severe bleeding	
FMD		Tap or gently shake person	
communication		Shout “are you ok?” or other appropriate question **[no response]**	
communication	comm	Indicate to team member that there is no response	
FMD		Open airway (tilt head back and lift chin)	
FMC		Look, listen, and feel for 5 seconds **[not breathing]**	
FMD		Position victim onto back (if necessary)	
FMC		Look, listen, and feel for 5 seconds **[not breathing]**	
cognitive	coord	Determine if victim is breathing	
communication	comm	Indicate to team member that victim is not breathing	
FMD	adapt	Give 2 slow breaths with BVM	
visual		Watch chest to see that breaths go in **[breaths go in]**	
visual		Locate adam’s apple	
FMD		Slide fingers into groove on neck	
FMC		Feel for pulse for 5 to 10 seconds **[no pulse]**	
cognitive	coord	Determine if there is a pulse	
visual/FMD	coord	Locate hand position while R1 checks pulse	
communication	comm adapt	Say “no pulse, begin CPR”	
GML	coord	Give compressions when R1 says “begin CPR”	
communication	comm	Count out loud “one and two and three and four and five”	
	coord	Stop compressions and allow R1 to ventilate	
FMD		Give 1 slow breath with BVM	
GML	coord	Resume compressions	
GML FMD	coord comm	Repeat cycles of 5 compressions and 1 breath for 1 minute	
cognitive	coord	Determine that it is time to check victim's pulse	
communication	comm	Say “pulse check”	
visual		Locate adam’s apple	
FMD		Slide fingers into groove on neck	
FMC		Feel for pulse for 5 to 10 seconds **[no breath, has pulse]**	
cognitive	coord	Determine if victim has a pulse	
visual/FMD	coord	Locate hand position while R1 checks pulse	
communication	comm adapt	Say “has pulse, continue rescue breathing”	
FMD		Give 1 slow breath with BVM	
communication	comm	Count out loud "one and two and three…"	

FMD/communication	coord	Repeat breathing and counting	
cognitive	coord	Determine that it is time to check victim's pulse	
communication	comm	Say "Check pulse"	
visual		Locate adam's apple	
FMD		Slide fingers into groove on neck	
FMC		Feel for pulse for 5 to 10 seconds **[no pulse]**	
cognitive	coord	Determine if there is a pulse	
visual/FMD	coord	Locate hand position while R1 checks pulse	
communication	comm	Say "no pulse, begin CPR"	
	adapt		
GML	coord	Give compressions when R1 says "begin CPR"	
communication	comm	Count out loud "one and two and three and four and five"	
	coord	Stop compressions and allow R1 to ventilate	
FMD		Give 1 slow breath with BVM	
GML	coord	Resume compressions	
GML	coord	Repeat cycles of 5 compressions and 1 breath for 1 minute	
FMD	comm		
cognitive	coord	Determine that it is time to check victim's pulse	
communication	comm	Say "pulse check"	
visual		Locate adam's apple	
FMD		Slide fingers into groove on neck	
FMC		Feel for pulse for 5 to 10 seconds **[no breath, no pulse]**	
cognitive	coord	Determine if victim has a pulse	
FMD	coord	Locate hand position while R1 checks pulse	
communication	comm	Say "no pulse, continue CPR"	
	adapt		
GML	coord	Give compressions when R1 says "begin CPR"	
communication	comm	Count out loud "one and two and three and four and five"	
	coord	Stop compressions and allow R1 to ventilate	
FMD	coord	Give 1 slow breath with BVM	
GML	coord	Resume compressions	
GML	coord	Repeat cycles of 5 compressions and 1 breath for 1 minute	
FMD	comm		
communication	comm	Say "pulse check"	
visual		Locate adam's apple	
FMD		Slide fingers into groove on neck	
FMC		Feel for pulse for 5 to 10 seconds **[victim is breathing and has pulse]**	
cognitive	coord	Determine if victim has a pulse	
FMD/visual	coord	Locate hand position while R1 checks pulse	
communication		Ask "are you ok?" or other appropriate question	

SIM 1

Taxon	Process	TARGET	HIT (L/M)
		Takes or verbalizes infection control procedures (put gloves on)	
visual		visually scan room for unsafe conditions	
cognitive	coord	determine if scene is okay	
communication	comm	communicate scene is ok or indicate potential problems	
communication		ask "what happened?" or other appropriate question **[fell from bunkbed]**	
cognitive	adapt	Determine head needs to be immobilized	
communication	comm	Communicate that head needs to immobilized	
communication	coord	Directs assistant to move patients head to the neutral in-line position	
communication	comm	Directs assistant to **maintain** manual immobilization of head	
	coord		
FMC	coord	Assistant holds head	
	adapt		
cognitive	coord	determine who will perform tasks	
communication	comm	verbally designate tasks	
visual		Look from head to toe for severe bleeding **[no severe bleeding]**	
cognitive	coord	Determine if there is severe bleeding	
communication	comm	communicate there is no severe bleeding	
FMD		Tap or gently shake person	
communication		Shout “are you ok?” or other appropriate question **[no response]**	
communication	comm	Indicate to team member that there is no response	
FMD		Open airway (tilt head back and lift chin)	
FMC		Look, listen, and feel for 5 seconds **[not breathing]**	
FMD		Position victim onto back (if necessary)	
FMC		Look, listen, and feel for 5 seconds **[not breathing]**	
cognitive	coord	Determine if victim is breathing	
communication	comm	Indicate to team member that victim is not breathing	
FMD	adapt	Give 2 slow breaths with BVM	
visual		Watch chest to see that breaths go in **[breaths DO NOT go in]**	
cognitive	coord	Determine breaths are not going in	
communication	comm	communicate "breaths not going in; victim choking"	
cognitive	adapt	Determine heimlich maneuver must be conducted	
	coord	assign tasks for heimlich	
	comm		
communication	adapt	Coordinate movements of assistant to perform heimlich	
cognitive	comm		
	coord		
FMD	adapt	position hands on stomach	

GML		push hands into stomach (3 times, then object comes out)	
cognitive	coord	Determine object is out and need to check airway	
FMD		Open airway (tilt head back and lift chin)	
visual/cognitive		Look, listen, and feel for 1 minute	
cognitive	coord	Determine victim is breathing	
communication	comm	Communicate victim is now breathing	
numerical		count BPM **[victim has 20 BPM]**	
cognitive	coord	Determine BPM is in normal range	
communication	comm	say "breathing in normal range"	
cognitive	coord	Determine need to check pulse	
visual		Locate adam's apple	
FMD		Slide fingers into groove on neck	
FMC		Feel for pulse for 5 to 10 seconds **[no pulse]**	
cognitive	coord	Determine if there is a pulse	
visual/FMD	coord	Locate hand position while R1 checks pulse	
communication	comm	Say "victim has pulse"	
cognitive	coord	Determine need to assess PMS	
FMC		check for pulse in feet	
cognitive	coord	determine if there is a pulse	
FMC		check for pulse in wrists	
cognitive	coord	determine if there is a pulse	
communication		ask questions like"which hand am I touching?" **[no response]**	
cognitive	coord	determine if victim's PMS is ok	
communication	comm	indicate victim's PMS is ok	
cognitive	coord	Determine need for cervical collar	
communication	adapt	direct assistant to put collar on or communicate intent to put collar on	
	comm		
FMD	adapt	place collar on neck	
FMD		secure collar	
FMD		Position backboard beside victim	
FMC	coord	One member maintain in-line mobilization	
communication	comm	Verbally direct movement of the patient	
	coord		
GML		Position board under the patient	
cognitive	coord	Decide movement method	
communication	comm	Communicate movement method choice	
GML	adapt	Move patient onto device without compromising the integrity of the spine	
FMD		Immobilize torso to the device using straps	
FMD		Secure legs to the device using straps	
FMD		Place pads beside head	
FMD		Tape forehead and chin to board	
cognitive	coord	Determine need to check PMS	
FMC		check for pulse in feet	
cognitive	coord	determine if there is a pulse	

FMC		check for pulse in wrists	
cognitive	coord	determine if there is a pulse	
communication		ask questions like"which hand am I touching?" **[no response]**	
cognitive	coord	determine if victim's PMS is ok	
communication	comm	indicate victim's PMS is ok	

SIM 2

Task Taxon	**Team Process**	**TARGET**	**HIT (L/M)**
		Takes or verbalizes infection control procedures (put gloves on)	
visual		visually scan room for unsafe conditions	
cognitive	coord	determine if scene is okay	
communication	comm	communicate scene is ok or indicate potential problems	
communication		ask "what happened?" or other appropriate question **[fight, severe neck pain]**	
cognitive	adapt	Determine head needs to be immobilized	
communication	comm	Communicate that head needs to immobilized	
communication	coord	Directs assistant to move patients head to the neutral in-line position	
communication	comm	Directs assistant to **maintain** manual immobilization of head	
	coord		
FMC	coord	Assistant holds head	
	adapt		
visual		Look from head to toe for severe bleeding **[no severe bleeding]**	
cognitive	coord	Determine if there is severe bleeding	
communication	comm	communicate there is no severe bleeding	
cognitive	coord	Determine need for cervical collar	
communication	adapt	direct assistant to put collar on or communicate intent to put collar on	
	comm		
FMD	adapt	place collar on neck	
FMD		secure collar	
cognitive	coord	Determine need to check PMS	
FMC		check for pulse in feet	
cognitive	coord	determine if there is a pulse	
FMC		check for pulse in wrists	
cognitive	coord	determine if there is a pulse	
communication		ask questions like"which hand am I touching?" **[correct answers]**	
cognitive	coord	determine if victim's PMS is ok	
communication	comm	indicate victim's PMS is ok	
FMD		Position backboard behind victim	

FMC	coord	One member maintain in-line mobilization	
communication	comm	Verbally direct movement of the patient	
	coord		
GML	adapt	Move patient onto device without compromising the integrity of the spine	
cognitive	coord	Determine movement method for 2-person standing	
	adapt		
communication	comm	Communicate movement method choice	
FMD	coord	Position arms around victim and board	
communication	comm	Direct lowering of victim to floor	
GMH	adapt	Lower victim to floor	
cognitive	coord	Determine victim needs to be rolled	
communication	adapt	Direct rolling of victim	
	comm		
GML	coord	roll victim	
FMC	coord	maintain in-line immobilization	
cognitive	coord	Determine victim is ready to be rolled back over	
	comm	Communicate to roll victim back over	
communication	adapt	Direct rolling of victim	
	comm		
GML	coord	roll victim	
FMD		Open airway (tilt head back and lift chin)	
FMC		Look, listen, and feel for 5 seconds **[breathing]**	
FMD		Position victim onto back (if necessary)	
FMC		Look, listen, and feel for 5 seconds [**breathing]**	
cognitive	coord	Determine if victim is breathing	
FMD		Immobilize torso to the device using straps	
FMD		Secure legs to the device using straps	
FMD		Place pads beside head	
FMD		Tape forehead and chin to board	
cognitive	coord	Determine need to check PMS	
FMC		check for pulse in feet	
cognitive	coord	determine if there is a pulse	
FMC		check for pulse in wrists	
cognitive	coord	determine if there is a pulse	
communication		ask questions like"which hand am I touching?" **[correct answers]**	
cognitive	coord	determine if victim's PMS is ok	
communication	comm	indicate victim's PMS is ok	

APPENDIX C

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
SIM 1	3	55	18.33333333	90.33333333
SIM 2	3	46	15.33333333	60.33333333
CPR 1	3	68	22.66666667	132.3333333
CPR 2	3	66	22	199

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	104.9166667	3	34.97222222	0.290225911	0.831417228	4.066180281
Within Groups	964	8	120.5			
Total	1068.916667	11				

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Adaptability	4	36	9	2.666666667
Communication	4	78	19.5	25.66666667
Coordination	4	121	30.25	26.91666667

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	903.1666667	2	451.5833333	24.52036199	0.000227664	4.256492048
Within Groups	165.75	9	18.41666667			
Total	1068.916667	11				

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
SIM 1	7	79	11.28571429	86.57142857
SIM 2	7	56	8	38
CPR 1	7	102	14.57142857	91.61904762
CPR 2	7	91	13	60

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	166.5714286	3	55.52380952	0.804137931	0.503875354	3.008786109
Within Groups	1657.142857	24	69.04761905			
Total	1823.714286	27				

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
visual	4	36	9	36.66666667
cognitive	4	75	18.75	14.25
FMD	4	74	18.5	56.33333333
FMC	4	34	8.5	1
GML	4	24	6	12.66666667
communication	4	83	20.75	15.58333333
GMH	4	2	0.5	0.333333333

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1413.214286	6	235.5357143	12.04933009	7.18969E-06	2.572711821
Within Groups	410.5	21	19.54761905			
Total	1823.714286	27				

APPENDIX D

Pre-Experiment Questionnaire

Background Information

1. What is your age?

2. What is your gender?

   Male   Female

3. What is your grade level in school? (Please circle one answer)

Freshman   Sophomore   Junior   Senior   Graduate Student   Not a student

Military Experience

4. Have you ever been a member of the Armed Forces (e.g. enlisted, officer, ROTC cadet, etc.)? If no, please skip to question 8.

   Yes   No

5. How long were you in the armed forces (number of months, years)?

6. What was your job in the Armed Forces?

7. Were you ever required to wear MOPP? If yes, for what?

Rescue Experience

8. What organization(s) are you certified by?

9. How long have you been certified rescuer (number of months, years)?

10. What are your specific roles and responsibilities on the rescue team?

11. Have you ever worn protective clothing while performing a rescue? If so, what type?

12. How many people do you typically perform a rescue with?

Training

13. How often do you train for rescue operations?

14. When was your last CPR training session?

14. When was your last spinal injury management training session?

Post-experiment Questionnaire

Questions 1-3 will ask you to evaluate your experience wearing MOPP during the rescue. Please circle the answer which best describes your experience.

1. Did wearing MOPP during the rescue affect your ability to adapt or respond to changing events (the victim having a seizure, for example) that occurred throughout the rescue?

Much less able to adapt	Somewhat less able to adapt	No effect	Somewhat more able to adapt	Much more able to adapt
1	2	3	4	5

2. Did wearing MOPP during the rescue affect your ability to communicate during the rescue?

Much less able to communicate	Somewhat less able to communicate	No effect	Somewhat more able to communicate	Much more able to communicate
1	2	3	4	5

3. Did wearing MOPP during the rescue affect your ability to coordinate as a team during the rescue?

Much less able to coordinate	Somewhat less able to coordinate	No effect	Somewhat more able to coordinate	Much more able to coordinate
1	2	3	4	5

Questions 4 - 6 ask you to rate your performance, your team member's performance, and your team's performance as a unit during the tasks. For each question, please circle the answer which best describes your opinion.

4. How would you rate your own individual performance during the rescue?

Very poor	Poor	Neither good nor poor	Good	Very good
1	2	3	4	5

5. How would you rate your team member's performance during the rescue?

Very poor	Poor	Neither good nor poor	Good	Very good
1	2	3	4	5

6. How would you rate your team's performance as a unit during the rescue?

Very poor	Poor	Neither good nor poor	Good	Very good
1	2	3	4	5

Questions 7-10 ask you to provide feedback about your experiences during the rescue tasks.

Please be as specific as possible.

7. How did you overcome, deal with, or ignore any adverse effects of wearing MOPP during the rescue?

8. Did you feel that you were accustomed to the MOPP before starting the experiment? If not, at what point did you get used to it?

9. What was the most difficult part of the experiment?

10. Do you have any suggestions for improving the design of MOPP?

Self-Report Questionnaire

For the following questions, please circle the response that best describes how well you agree or disagree with each statement.

1. Members of my team knew how to perform their required tasks

1	2	3	4	5
Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree

2. Members of my team discussed ideas about how to proceed in the rescue.

1	2	3	4	5
Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree

3. Members of my team cooperated with each other during the rescue process.

1	2	3	4	5
Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree

4. Members of my team did not do their best during the rescues.

1	2	3	4	5
Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree

5. My team felt that the success of our team was the most important objective of this exercise.

1	2	3	4	5
Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree

6. Members of my team told me about the things I needed to know to do my job.

1	2	3	4	5
Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree

7. Members of my team felt under pressure during the rescues.

1	2	3	4	5
Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree

8. When members of my team had questions, we could ask each other for help.

1	2	3	4	5
Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree

9. Members of my team had confidence in the accuracy of the information we got from each other.

1	2	3	4	5
Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree

10. Communications were always clear among members of my team.

1	2	3	4	5
Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree

11. The activities of my team were well organized.

1	2	3	4	5
Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree

12. I knew exactly what I was supposed to do during the exercises.

1	2	3	4	5
Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree

13. My team felt that the success of individual members was the most importatnt objective of the rescues.

1	2	3	4	5
Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree

14. Success in my job depended heavily upon the actions of the other team member.

1	2	3	4	5
Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree

15. It took too long to coordinate information in my team.

1	2	3	4	5
Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree

16. I completely understood how my position fit in with the work of other members of the team.

1	2	3	4	5
Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree

17. I was not satisfied with my team's performance during the rescues.

1	2	3	4	5
Strongly disagree	Disagree	Neither disagree nor agree	Agree	Strongly Agree

APPENDIX E

APPENDIX F

t-Test: Paired Two Sample for Means   Task main effect

	CPR	SIM
Mean	0.5003	0.65506667
Variance	0.041980079	0.03961048
Observations	30	30
Pearson Correlation	0.384818399	
Hypothesized Mean Difference	0	
df	29	
t Stat	-3.78319866	
P(T<=t) one-tail	0.000359176	
t Critical one-tail	1.699127097	
P(T<=t) two-tail	0.000718353	
t Critical two-tail	2.045230758	

t-Test: Paired Two Sample for Means   Task x Process Interaction--CPR

	Adaptability	Communication
Mean	0.5046	0.5063
Variance	0.054706267	0.04308379
Observations	10	10
Pearson Correlation	0.70831445	
Hypothesized Mean Difference	0	
df	9	
t Stat	-0.0315601	
P(T<=t) one-tail	0.487755838	
t Critical one-tail	1.833113856	
P(T<=t) two-tail	0.975511675	
t Critical two-tail	2.262158887	

t-Test: Paired Two Sample for Means   Task x Process Interaction--CPR

	Adaptability	Coordination
Mean	0.5046	0.49
Variance	0.054706267	0.03730067
Observations	10	10
Pearson Correlation	0.35720625	
Hypothesized Mean Difference	0	
df	9	
t Stat	0.188902917	
P(T<=t) one-tail	0.427180027	
t Critical one-tail	1.833113856	
P(T<=t) two-tail	0.854360054	
t Critical two-tail	2.262158887	

t-Test: Paired Two Sample for Means   Task x Process Interaction--CPR

	Communication	Coordination

Mean	0.5063	0.49
Variance	0.043083789	0.03730067
Observations	10	10
Pearson Correlation	0.879277749	
Hypothesized Mean Difference	0	
df	9	
t Stat	0.518379445	
P(T<=t) one-tail	0.308347987	
t Critical one-tail	1.833113856	
P(T<=t) two-tail	0.616695974	
t Critical two-tail	2.262158887	

t-Test: Paired Two Sample for Means   Task x Process Interaction--SIM

	Adaptability	*Communication*
Mean	0.8002	0.6041
Variance	0.0158804	0.03092921
Observations	10	10
Pearson Correlation	0.742259974	
Hypothesized Mean Difference	0	
df	9	
t Stat	5.258069767	
P(T<=t) one-tail	0.000261035	
t Critical one-tail	1.833113856	
P(T<=t) two-tail	0.00052207	
t Critical two-tail	2.262158887	

t-Test: Paired Two Sample for Means   Task x Process Interaction--SIM

	Adaptability	*Coordination*
Mean	0.8002	0.5609
Variance	0.0158804	0.04468121
Observations	10	10
Pearson Correlation	0.821929507	
Hypothesized Mean Difference	0	
df	9	
t Stat	5.842959364	
P(T<=t) one-tail	0.000122954	
t Critical one-tail	1.833113856	
P(T<=t) two-tail	0.000245908	
t Critical two-tail	2.262158887	

t-Test: Paired Two Sample for Means   Task x Process Interaction--SIM

	Communication	*Coordination*
Mean	0.6041	0.5609
Variance	0.030929211	0.04468121
Observations	10	10
Pearson Correlation	0.82082249	
Hypothesized Mean Difference	0	
df	9	

t Stat	1.131260505
P(T<=t) one-tail	0.143593838
t Critical one-tail	1.833113856
P(T<=t) two-tail	0.287187675
t Critical two-tail	2.262158887

t-Test: Paired Two Sample for Means   Process main effect

	Adaptability	*Communication*
Mean	0.6524	0.5552
Variance	0.056430358	0.03757585
Observations	20	20
Pearson Correlation	0.688170156	
Hypothesized Mean Difference	0	
df	19	
t Stat	2.483810797	
P(T<=t) one-tail	0.011247185	
t Critical one-tail	1.729131327	
P(T<=t) two-tail	0.022494371	
t Critical two-tail	2.093024705	

t-Test: Paired Two Sample for Means   Process main effect

	Adaptability	*Coordination*
Mean	0.6524	0.52545
Variance	0.056430358	0.04015637
Observations	20	20
Pearson Correlation	0.494287889	
Hypothesized Mean Difference	0	
df	19	
t Stat	2.551079156	
P(T<=t) one-tail	0.009757161	
t Critical one-tail	1.729131327	
P(T<=t) two-tail	0.019514321	
t Critical two-tail	2.093024705	

t-Test: Paired Two Sample for Means   Process main effect

	Communication	*Coordination*
Mean	0.5552	0.52545
Variance	0.037575853	0.04015637
Observations	20	20
Pearson Correlation	0.848901848	
Hypothesized Mean Difference	0	
df	19	
t Stat	1.225745935	
P(T<=t) one-tail	0.117635557	
t Critical one-tail	1.729131327	

P(T<=t) two-tail	0.235271113	
t Critical two-tail	2.093024705	

t-Test: Paired Two Sample for Means

	T1	*T2*
Mean	0.633083333	0.71266667
Variance	0.019743174	0.01586024
Observations	12	12
Pearson Correlation	0.342610202	
Hypothesized Mean Difference	0	
df	11	
t Stat	-1.79920823	
P(T<=t) one-tail	0.049723592	
t Critical one-tail	1.795883691	
P(T<=t) two-tail	0.099447185	
t Critical two-tail	2.200986273	

t-Test: Paired Two Sample for Means

	T1	*T3*
Mean	0.633083333	0.69175
Variance	0.019743174	0.03470039
Observations	12	12
Pearson Correlation	0.259526441	
Hypothesized Mean Difference	0	
df	11	
t Stat	-1.00541438	
P(T<=t) one-tail	0.16815097	
t Critical one-tail	1.795883691	
P(T<=t) two-tail	0.336301939	
t Critical two-tail	2.200986273	

t-Test: Paired Two Sample for Means

	T1	*T4*
Mean	0.633083333	0.38341667
Variance	0.019743174	0.05448027
Observations	12	12
Pearson Correlation	0.278930665	
Hypothesized Mean Difference	0	
df	11	
t Stat	3.657113373	
P(T<=t) one-tail	0.001886781	
t Critical one-tail	1.795883691	
P(T<=t) two-tail	0.003773561	
t Critical two-tail	2.200986273	

t-Test: Paired Two Sample for Means

	T1	T5
Mean	0.633083333	0.4675
Variance	0.019743174	0.03114755
Observations	12	12
Pearson Correlation	0.860133425	
Hypothesized Mean Difference	0	
df	11	
t Stat	6.32231815	
P(T<=t) one-tail	2.82931E-05	
t Critical one-tail	1.795883691	
P(T<=t) two-tail	5.65862E-05	
t Critical two-tail	2.200986273	

t-Test: Paired Two Sample for Means

	T2	T3
Mean	0.712666667	0.69175
Variance	0.015860242	0.03470039
Observations	12	12
Pearson Correlation	0.216266619	
Hypothesized Mean Difference	0	
df	11	
t Stat	0.360428947	
P(T<=t) one-tail	0.362675964	
t Critical one-tail	1.795883691	
P(T<=t) two-tail	0.725351927	
t Critical two-tail	2.200986273	

t-Test: Paired Two Sample for Means

	T2	T4
Mean	0.712666667	0.38341667
Variance	0.015860242	0.05448027
Observations	12	12
Pearson Correlation	0.757030644	
Hypothesized Mean Difference	0	
df	11	
t Stat	7.096035888	
P(T<=t) one-tail	1.00171E-05	
t Critical one-tail	1.795883691	
P(T<=t) two-tail	2.00342E-05	
t Critical two-tail	2.200986273	

t-Test: Paired Two Sample for Means

	T2	T5
Mean	0.712666667	0.4675
Variance	0.015860242	0.03114755
Observations	12	12
Pearson Correlation	0.181566373	
Hypothesized Mean Difference	0	

df	11	
t Stat	4.304002271	
P(T<=t) one-tail	0.000623791	
t Critical one-tail	1.795883691	
P(T<=t) two-tail	0.001247582	
t Critical two-tail	2.200986273	

t-Test: Paired Two Sample for Means

	T3	*T4*
Mean	0.69175	0.38341667
Variance	0.034700386	0.05448027
Observations	12	12
Pearson Correlation	0.434871996	
Hypothesized Mean Difference	0	
df	11	
t Stat	4.71280954	
P(T<=t) one-tail	0.000318403	
t Critical one-tail	1.795883691	
P(T<=t) two-tail	0.000636805	
t Critical two-tail	2.200986273	

t-Test: Paired Two Sample for Means

	T3	*T5*
Mean	0.69175	0.4675
Variance	0.034700386	0.03114755
Observations	12	12
Pearson Correlation	0.459753627	
Hypothesized Mean Difference	0	
df	11	
t Stat	4.116110858	
P(T<=t) one-tail	0.000855975	
t Critical one-tail	1.795883691	
P(T<=t) two-tail	0.001711949	
t Critical two-tail	2.200986273	

t-Test: Paired Two Sample for Means

	T4	*T5*
Mean	0.383416667	0.4675
Variance	0.054480265	0.03114755
Observations	12	12
Pearson Correlation	0.056843329	
Hypothesized Mean Difference	0	
df	11	
t Stat	-1.02377973	
P(T<=t) one-tail	0.163963572	
t Critical one-tail	1.795883691	
P(T<=t) two-tail	0.327927144	
t Critical two-tail	2.200986273	

t-Test: Paired Two Sample for Means

	M1	*M2*
Mean	0.187333333	0.19608333
Variance	0.021574606	0.01663772
Observations	12	12
Pearson Correlation	0.66520834	
Hypothesized Mean Difference	0	
df	11	
t Stat	-0.26578067	
P(T<=t) one-tail	0.39766178	
t Critical one-tail	1.795883691	
P(T<=t) two-tail	0.79532356	
t Critical two-tail	2.200986273	

t-Test: Paired Two Sample for Means

	M1	*M3*
Mean	0.187333333	0.15325
Variance	0.021574606	0.0137402
Observations	12	12
Pearson Correlation	0.540309063	
Hypothesized Mean Difference	0	
df	11	
t Stat	0.913382798	
P(T<=t) one-tail	0.190312703	
t Critical one-tail	1.795883691	
P(T<=t) two-tail	0.380625405	
t Critical two-tail	2.200986273	

t-Test: Paired Two Sample for Means

	M1	*M4*
Mean	0.187333333	0.39191667
Variance	0.021574606	0.02393045
Observations	12	12
Pearson Correlation	0.171561022	
Hypothesized Mean Difference	0	
df	11	
t Stat	-3.64955996	
P(T<=t) one-tail	0.001911836	
t Critical one-tail	1.795883691	
P(T<=t) two-tail	0.003823672	
t Critical two-tail	2.200986273	

t-Test: Paired Two Sample for Means

	M1	*M5*
Mean	0.187333333	0.31475

Variance	0.021574606	0.03283548
Observations	12	12
Pearson Correlation	0.73416825	
Hypothesized Mean Difference	0	
df	11	
t Stat	-3.56502544	
P(T<=t) one-tail	0.002216792	
t Critical one-tail	1.795883691	
P(T<=t) two-tail	0.004433585	
t Critical two-tail	2.200986273	

t-Test: Paired Two Sample for Means

	M2	*M3*
Mean	0.196083333	0.15325
Variance	0.01663772	0.0137402
Observations	12	12
Pearson Correlation	0.15594183	
Hypothesized Mean Difference	0	
df	11	
t Stat	0.926241904	
P(T<=t) one-tail	0.187097727	
t Critical one-tail	1.795883691	
P(T<=t) two-tail	0.374195454	
t Critical two-tail	2.200986273	

t-Test: Paired Two Sample for Means

	M2	*M4*
Mean	0.196083333	0.39191667
Variance	0.01663772	0.02393045
Observations	12	12
Pearson Correlation	#N/A	
Hypothesized Mean Difference	0	
df	11	
t Stat	-5.05979908	
P(T<=t) one-tail	0.000183199	
t Critical one-tail	1.795883691	
P(T<=t) two-tail	0.000366398	
t Critical two-tail	2.200986273	

t-Test: Paired Two Sample for Means

	M2	*M5*
Mean	0.196083333	0.31475
Variance	0.01663772	0.03283548
Observations	12	12
Pearson Correlation	0.304739768	
Hypothesized Mean Difference	0	
df	11	
t Stat	-2.19016705	

P(T<=t) one-tail	0.02547669	
t Critical one-tail	1.795883691	
P(T<=t) two-tail	0.05095338	
t Critical two-tail	2.200986273	

t-Test: Paired Two Sample for Means

	M3	*M4*
Mean	0.15325	0.39191667
Variance	0.013740205	0.02393045
Observations	12	12
Pearson Correlation	-0.32727071	
Hypothesized Mean Difference	0	
df	11	
t Stat	-3.71455262	
P(T<=t) one-tail	0.001706995	
t Critical one-tail	1.795883691	
P(T<=t) two-tail	0.00341399	
t Critical two-tail	2.200986273	

t-Test: Paired Two Sample for Means

	M3	*M5*
Mean	0.15325	0.31475
Variance	0.013740205	0.03283548
Observations	12	12
Pearson Correlation	0.801638498	
Hypothesized Mean Difference	0	
df	11	
t Stat	-4.9996965	
P(T<=t) one-tail	0.000201361	
t Critical one-tail	1.795883691	
P(T<=t) two-tail	0.000402723	
t Critical two-tail	2.200986273	

t-Test: Paired Two Sample for Means

	M4	*M5*
Mean	0.391916667	0.31475
Variance	0.023930447	0.03283548
Observations	12	12
Pearson Correlation	-0.03654081	
Hypothesized Mean Difference	0	
df	11	
t Stat	1.102244913	
P(T<=t) one-tail	0.14694371	
t Critical one-tail	1.795883691	
P(T<=t) two-tail	0.29388742	
t Critical two-tail	2.200986273	

t-Test: Paired Two Sample for Means Task x Process Interaction--CPR

	Adaptability	*Communication*
Mean	0.2109	0.2877
Variance	0.023460767	0.01889446
Observations	10	10
Pearson Correlation	0.316151026	
Hypothesized Mean Difference	0	
df	9	
t Stat	-1.42509333	
P(T<=t) one-tail	0.093936463	
t Critical one-tail	1.833113856	
P(T<=t) two-tail	0.187872927	
t Critical two-tail	2.262158887	

t-Test: Paired Two Sample for Means   Task x Process Interaction--CPR

	Adaptability	*Coordination*
Mean	0.2109	0.3687
Variance	0.023460767	0.02139623
Observations	10	10
Pearson Correlation	-0.04979751	
Hypothesized Mean Difference	0	
df	9	
t Stat	-2.29958799	
P(T<=t) one-tail	0.023515542	
t Critical one-tail	1.833113856	
P(T<=t) two-tail	0.047031085	
t Critical two-tail	2.262158887	

t-Test: Paired Two Sample for Means   Task x Process Interaction--CPR

	Communication	*Coordination*
Mean	0.2877	0.3687
Variance	0.018894456	0.02139623
Observations	10	10
Pearson Correlation	0.865255432	
Hypothesized Mean Difference	0	
df	9	
t Stat	-3.45503839	
P(T<=t) one-tail	0.003608544	
t Critical one-tail	1.833113856	
P(T<=t) two-tail	0.007217088	
t Critical two-tail	2.262158887	

t-Test: Paired Two Sample for Means   Task x Process Interaction--SIM

	Adaptability	*Communication*
Mean	0.3443	0.0872
Variance	0.028730678	0.01750084
Observations	10	10

Pearson Correlation	0.697471215
Hypothesized Mean Difference	0
df	9
t Stat	6.64891805
P(T<=t) one-tail	4.69273E-05
t Critical one-tail	1.833113856
P(T<=t) two-tail	9.38547E-05
t Critical two-tail	2.262158887

t-Test: Paired Two Sample for Means   Task x Process Interaction--SIM

	Adaptability	*Coordination*
Mean	0.3443	0.1932
Variance	0.028730678	0.01508484
Observations	10	10
Pearson Correlation	0.711852266	
Hypothesized Mean Difference	0	
df	9	
t Stat	4.013093445	
P(T<=t) one-tail	0.001524812	
t Critical one-tail	1.833113856	
P(T<=t) two-tail	0.003049625	
t Critical two-tail	2.262158887	

t-Test: Paired Two Sample for Means   Task x Process Interaction--SIM

	Communication	*Coordination*
Mean	0.0872	0.1932
Variance	0.017500844	0.01508484
Observations	10	10
Pearson Correlation	0.784298904	
Hypothesized Mean Difference	0	
df	9	
t Stat	-3.97835816	
P(T<=t) one-tail	0.001606882	
t Critical one-tail	1.833113856	
P(T<=t) two-tail	0.003213764	
t Critical two-tail	2.262158887	

t-Test: Paired Two Sample for Means

	adapt	comm
	Variable 1	*Variable 2*
Mean	0.83925	0.682
Variance	0.0385837	0.0106788
Observations	20	20
Pearson Correlation	0.2922825	
Hypothesized Mean Difference	0	
df	19	
t Stat	3.6365442	
P(T<=t) one-tail	0.0008781	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	0.0017561	
t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means

	adapt	coord
	Variable 1	*Variable 2*
Mean	0.83925	0.7271
Variance	0.0385837	0.0199906
Observations	20	20
Pearson Correlation	-0.1284184	
Hypothesized Mean Difference	0	
df	19	
t Stat	1.9566245	
P(T<=t) one-tail	0.0326259	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	0.0652517	
t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means

	comm	coord
	Variable 1	*Variable 2*
Mean	0.682	0.7271
Variance	0.0106788	0.0199906
Observations	20	20
Pearson Correlation	0.6333365	
Hypothesized Mean Difference	0	
df	19	
t Stat	-1.8288732	
P(T<=t) one-tail	0.0415801	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	0.0831603	
t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means cpr:adapt, comm

	Variable 1	Variable 2
Mean	0.6785	0.6782
Variance	0.0240309	0.011562
Observations	10	10
Pearson Correlation	0.6699726	
Hypothesized Mean Difference	0	
df	9	
t Stat	0.0082392	
P(T<=t) one-tail	0.4968029	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.9936059	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means cpr:adapt, coord

	Variable 1	Variable 2
Mean	0.6785	0.7648
Variance	0.0240309	0.0055455
Observations	10	10
Pearson Correlation	0.5143799	
Hypothesized Mean Difference	0	
df	9	
t Stat	-2.0512499	
P(T<=t) one-tail	0.0352355	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.0704711	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means cpr:comm, coord

	Variable 1	Variable 2
Mean	0.6782	0.7648
Variance	0.011562	0.0055455
Observations	10	10
Pearson Correlation	0.8531847	
Hypothesized Mean Difference	0	
df	9	
t Stat	-4.6664167	
P(T<=t) one-tail	0.0005873	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.0011745	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means sim:adapt,comm

	Variable 1	Variable 2
Mean	1	0.6858
Variance	0	0.0109502

Observations	10	10
Pearson Correlation	#DIV/0!	
Hypothesized Mean Difference	0	
df	9	
t Stat	9.4950137	
P(T<=t) one-tail	2.749E-06	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	5.498E-06	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means sim: adapt, coord

	Variable 1	*Variable 2*
Mean	1	0.6894
Variance	0	0.0334985
Observations	10	10
Pearson Correlation	#DIV/0!	
Hypothesized Mean Difference	0	
df	9	
t Stat	5.3664717	
P(T<=t) one-tail	0.0002262	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.0004525	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	Variable 1	*Variable 2*
Mean	0.6858	0.6894
Variance	0.0109502	0.0334985
Observations	10	10
Pearson Correlation	0.6799136	
Hypothesized Mean Difference	0	
df	9	
t Stat	-0.0839147	
P(T<=t) one-tail	0.4674806	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.9349611	
t Critical two-tail	2.2621589	

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t-Test: Paired Two Sample for Means

	Cognitive	*Communication*
Mean	0.6772	0.62965
Variance	0.0391257	0.01630045
Observations	20	20
Pearson Correlation	0.5799015	
Hypothesized Mean Difference	0	
df	19	
t Stat	1.3153522	
P(T<=t) one-tail	0.1020224	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	0.2040449	
t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means

	Cognitive	*FMC*
Mean	0.6772	0.74845
Variance	0.0391257	0.058025208
Observations	20	20
Pearson Correlation	0.804552	
Hypothesized Mean Difference	0	
df	19	
t Stat	-2.2264946	
P(T<=t) one-tail	0.019138	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	0.0382761	
t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means

	Cognitive	*FMD*
Mean	0.6772	0.8111
Variance	0.0391257	0.0178282
Observations	20	20
Pearson Correlation	-0.2788936	
Hypothesized Mean Difference	0	
df	19	
t Stat	-2.236554	
P(T<=t) one-tail	0.0187518	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	0.0375036	
t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means

	Cognitive	*GMH*
Mean	0.6772	0.6
Variance	0.0391257	0.252631579
Observations	20	20
Pearson Correlation	0.1289581	
Hypothesized Mean Difference	0	
df	19	
t Stat	0.669264	
P(T<=t) one-tail	0.2556892	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	0.5113784	
t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means

	Cognitive	*GML*
Mean	0.6772	0.95725
Variance	0.0391257	0.011976197
Observations	20	20
Pearson Correlation	0.1122551	
Hypothesized Mean Difference	0	
df	19	
t Stat	-5.8241431	
P(T<=t) one-tail	6.534E-06	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	1.307E-05	
t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means

	Cognitive	*Visual*
Mean	0.6772	0.54095
Variance	0.0391257	0.049223103
Observations	20	20
Pearson Correlation	0.3139862	
Hypothesized Mean Difference	0	
df	19	
t Stat	2.4713506	
P(T<=t) one-tail	0.0115456	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	0.0230913	
t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means

	Communication	*FMC*
Mean	0.62965	0.74845
Variance	0.0163005	0.058025208

Observations	20	20
Pearson Correlation	0.4388737	
Hypothesized Mean Difference	0	
df	19	
t Stat	-2.4420725	
P(T<=t) one-tail	0.0122764	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	0.0245528	
t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means

	Communication	*FMD*
Mean	0.62965	0.8111
Variance	0.0163005	0.0178282
Observations	20	20
Pearson Correlation	0.3766001	
Hypothesized Mean Difference	0	
df	19	
t Stat	-5.5615723	
P(T<=t) one-tail	1.152E-05	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	2.304E-05	
t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means

	Communication	*GMH*
Mean	0.62965	0.6
Variance	0.0163005	0.252631579
Observations	20	20
Pearson Correlation	0.5898648	
Hypothesized Mean Difference	0	
df	19	
t Stat	0.3016519	
P(T<=t) one-tail	0.3830971	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	0.7661942	
t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means

	Communication	*GML*
Mean	0.62965	0.95725
Variance	0.0163005	0.011976197
Observations	20	20
Pearson Correlation	0.2163713	
Hypothesized Mean Difference	0	

df	19	
t Stat	-9.8262015	
P(T<=t) one-tail	3.488E-09	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	6.975E-09	
t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means

	Communication	*Visual*
Mean	0.62965	0.54095
Variance	0.0163005	0.049223103
Observations	20	20
Pearson Correlation	-0.0744294	
Hypothesized Mean Difference	0	
df	19	
t Stat	1.5020946	
P(T<=t) one-tail	0.0747554	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	0.1495107	
t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means

	FMC	*FMD*
Mean	0.74845	0.8111
Variance	0.0580252	0.0178282
Observations	20	20
Pearson Correlation	-0.0086808	
Hypothesized Mean Difference	0	
df	19	
t Stat	-1.0135748	
P(T<=t) one-tail	0.16176	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	0.32352	
t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means

	FMC	*GMH*
Mean	0.74845	0.6
Variance	0.0580252	0.252631579
Observations	20	20
Pearson Correlation	-0.0214744	
Hypothesized Mean Difference	0	
df	19	
t Stat	1.1812725	
P(T<=t) one-tail	0.1260351	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	0.2520701	

t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means

	FMC	*GML*
Mean	0.74845	0.95725
Variance	0.0580252	0.011976197
Observations	20	20
Pearson Correlation	-0.0166117	
Hypothesized Mean Difference	0	
df	19	
t Stat	-3.5074554	
P(T<=t) one-tail	0.0011776	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	0.0023552	
t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means

	FMC	*Visual*
Mean	0.74845	0.54095
Variance	0.0580252	0.049223103
Observations	20	20
Pearson Correlation	0.2364362	
Hypothesized Mean Difference	0	
df	19	
t Stat	3.2410705	
P(T<=t) one-tail	0.0021496	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	0.0042991	
t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means

	FMD	*GMH*
Mean	0.8111	0.6
Variance	0.0178282	0.252631579
Observations	20	20
Pearson Correlation	0.277464	
Hypothesized Mean Difference	0	
df	19	
t Stat	1.9548908	
P(T<=t) one-tail	0.0327349	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	0.0654698	
t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means

	FMD	*GML*

Mean	0.8111	0.95725
Variance	0.0178282	0.011976197
Observations	20	20
Pearson Correlation	0.0418128	
Hypothesized Mean Difference	0	
df	19	
t Stat	-3.86602	
P(T<=t) one-tail	0.0005203	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	0.0010405	
t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means

	FMD	*Visual*
Mean	0.8111	0.54095
Variance	0.0178282	0.049223103
Observations	20	20
Pearson Correlation	-0.4086708	
Hypothesized Mean Difference	0	
df	19	
t Stat	3.9991749	
P(T<=t) one-tail	0.0003838	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	0.0007676	
t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means

	GMH	*GML*
Mean	0.6	0.95725
Variance	0.2526316	0.011976197
Observations	20	20
Pearson Correlation	0.182758	
Hypothesized Mean Difference	0	
df	19	
t Stat	-3.2310641	
P(T<=t) one-tail	0.0021984	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	0.0043968	
t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means

	GMH	*Visual*
Mean	0.6	0.54095
Variance	0.2526316	0.049223103
Observations	20	20
Pearson Correlation	-0.0780645	
Hypothesized Mean Difference	0	
df	19	

t Stat	0.4673681
P(T<=t) one-tail	0.322776
t Critical one-tail	1.7291313
P(T<=t) two-tail	0.6455521
t Critical two-tail	2.0930247

t-Test: Paired Two Sample for Means

	GML	*Visual*
Mean	0.95725	0.54095
Variance	0.0119762	0.049223103
Observations	20	20
Pearson Correlation	-0.2175775	
Hypothesized Mean Difference	0	
df	19	
t Stat	6.9496963	
P(T<=t) one-tail	6.341E-07	
t Critical one-tail	1.7291313	
P(T<=t) two-tail	1.268E-06	
t Critical two-tail	2.0930247	

t-Test: Paired Two Sample for Means

	Cognitive	*Communication*
Mean	0.6107	0.6488
Variance	0.0578733	0.020118622
Observations	10	10
Pearson Correlation	0.6171961	
Hypothesized Mean Difference	0	
df	9	
t Stat	-0.636135	
P(T<=t) one-tail	0.2702632	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.5405263	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	Cognitive	*FMC*
Mean	0.6107	0.6256
Variance	0.0578733	0.073432267
Observations	10	10
Pearson Correlation	0.9301232	
Hypothesized Mean Difference	0	
df	9	
t Stat	-0.4703416	
P(T<=t) one-tail	0.3246501	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.6493002	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	Cognitive	*FMD*
Mean	0.6107	0.8803
Variance	0.0578733	0.013625567
Observations	10	10
Pearson Correlation	-0.0724449	
Hypothesized Mean Difference	0	
df	9	
t Stat	-3.1013592	
P(T<=t) one-tail	0.0063473	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.0126946	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	Cognitive	*GMH*
Mean	0.6107	0.7
Variance	0.0578733	0.233333333
Observations	10	10
Pearson Correlation	0.0058326	
Hypothesized Mean Difference	0	
df	9	
t Stat	-0.5245223	
P(T<=t) one-tail	0.306294	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.6125879	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	Cognitive	*GML*
Mean	0.6107	0.9667
Variance	0.0578733	0.0110889
Observations	10	10
Pearson Correlation	0.0667474	
Hypothesized Mean Difference	0	
df	9	
t Stat	-4.396052	
P(T<=t) one-tail	0.0008651	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.0017303	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	Cognitive	*Visual*
Mean	0.6107	0.45
Variance	0.0578733	0.074395111

Observations	10	10
Pearson Correlation	0.1685778	
Hypothesized Mean Difference	0	
df	9	
t Stat	1.5312016	
P(T<=t) one-tail	0.0800397	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.1600795	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	Communication	*FMC*
Mean	0.6488	0.6256
Variance	0.0201186	0.073432267
Observations	10	10
Pearson Correlation	0.7520425	
Hypothesized Mean Difference	0	
df	9	
t Stat	0.3880744	
P(T<=t) one-tail	0.3534903	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.7069805	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	Communication	*FMD*
Mean	0.6488	0.8803
Variance	0.0201186	0.013625567
Observations	10	10
Pearson Correlation	0.6127096	
Hypothesized Mean Difference	0	
df	9	
t Stat	-6.3111202	
P(T<=t) one-tail	6.957E-05	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.0001391	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	Communication	*GMH*
Mean	0.6488	0.7
Variance	0.0201186	0.233333333
Observations	10	10
Pearson Correlation	0.5779732	
Hypothesized Mean Difference	0	

df	9	
t Stat	-0.3878655	
P(T<=t) one-tail	0.3535649	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.7071298	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	Communication	*GML*
Mean	0.6488	0.9667
Variance	0.0201186	0.0110889
Observations	10	10
Pearson Correlation	0.031708	
Hypothesized Mean Difference	0	
df	9	
t Stat	-5.7790141	
P(T<=t) one-tail	0.0001332	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.0002664	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	Communication	*Visual*
Mean	0.6488	0.45
Variance	0.0201186	0.074395111
Observations	10	10
Pearson Correlation	-0.1763501	
Hypothesized Mean Difference	0	
df	9	
t Stat	1.9115487	
P(T<=t) one-tail	0.0441213	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.0882426	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	FMC	*FMD*
Mean	0.6256	0.8803
Variance	0.0734323	0.013625567
Observations	10	10
Pearson Correlation	0.1885325	
Hypothesized Mean Difference	0	
df	9	
t Stat	-2.9384634	
P(T<=t) one-tail	0.008264	
t Critical one-tail	1.8331139	

P(T<=t) two-tail	0.016528	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	FMC	*GMH*
Mean	0.6256	0.7
Variance	0.0734323	0.233333333
Observations	10	10
Pearson Correlation	0.0838654	
Hypothesized Mean Difference	0	
df	9	
t Stat	-0.4408545	
P(T<=t) one-tail	0.334859	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.669718	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	FMC	*GML*
Mean	0.6256	0.9667
Variance	0.0734323	0.0110889
Observations	10	10
Pearson Correlation	0.090245	
Hypothesized Mean Difference	0	
df	9	
t Stat	-3.8287008	
P(T<=t) one-tail	0.0020179	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.0040357	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	FMD	*GMH*
Mean	0.8803	0.7
Variance	0.0136256	0.233333333
Observations	10	10
Pearson Correlation	0.5594448	
Hypothesized Mean Difference	0	
df	9	
t Stat	1.329659	
P(T<=t) one-tail	0.1081724	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.2163447	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	FMC	*Visual*
Mean	0.6256	0.45
Variance	0.0734323	0.074395111
Observations	10	10
Pearson Correlation	-0.0466244	
Hypothesized Mean Difference	0	
df	9	
t Stat	1.4117307	
P(T<=t) one-tail	0.0958274	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.1916547	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	FMD	*GML*
Mean	0.8803	0.9667
Variance	0.0136256	0.0110889
Observations	10	10
Pearson Correlation	0.0701352	
Hypothesized Mean Difference	0	
df	9	
t Stat	-1.8019459	
P(T<=t) one-tail	0.0525333	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.1050666	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	FMD	*Visual*
Mean	0.8803	0.45
Variance	0.0136256	0.074395111
Observations	10	10
Pearson Correlation	-0.4583931	
Hypothesized Mean Difference	0	
df	9	
t Stat	3.9745669	
P(T<=t) one-tail	0.0016161	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.0032322	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	GMH	*GML*
Mean	0.7	0.9667
Variance	0.2333333	0.0110889
Observations	10	10
Pearson Correlation	-0.2182179	
Hypothesized Mean Difference	0	

df	9	
t Stat	-1.6333334	
P(T<=t) one-tail	0.068416	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.136832	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	GMH	*Visual*
Mean	0.7	0.45
Variance	0.2333333	0.074395111
Observations	10	10
Pearson Correlation	-0.1264993	
Hypothesized Mean Difference	0	
df	9	
t Stat	1.3537033	
P(T<=t) one-tail	0.1044229	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.2088459	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	GML	*Visual*
Mean	0.9667	0.45
Variance	0.0110889	0.074395111
Observations	10	10
Pearson Correlation	-0.4933829	
Hypothesized Mean Difference	0	
df	9	
t Stat	4.8430361	
P(T<=t) one-tail	0.0004586	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.0009172	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	Cognitive	*Communication*
Mean	0.7437	0.6105
Variance	0.0148982	0.0134785
Observations	10	10
Pearson Correlation	0.8952849	
Hypothesized Mean Difference	0	
df	9	
t Stat	7.6860936	
P(T<=t) one-tail	1.522E-05	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	3.043E-05	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	Cognitive	*FMC*
Mean	0.7437	0.8713
Variance	0.0148982	0.015527344
Observations	10	10
Pearson Correlation	0.1406786	
Hypothesized Mean Difference	0	
df	9	
t Stat	-2.4954325	
P(T<=t) one-tail	0.0170583	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.0341165	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	Cognitive	*FMD*
Mean	0.7437	0.7419
Variance	0.0148982	0.013370322
Observations	10	10
Pearson Correlation	-0.2330791	
Hypothesized Mean Difference	0	
df	9	
t Stat	0.030492	
P(T<=t) one-tail	0.4881701	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.9763402	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	Cognitive	*GMH*
Mean	0.7437	0.5
Variance	0.0148982	0.277777778
Observations	10	10
Pearson Correlation	0.6399257	
Hypothesized Mean Difference	0	
df	9	
t Stat	1.6803194	
P(T<=t) one-tail	0.0635984	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.1271967	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	Cognitive	*GML*
Mean	0.7437	0.9478

Variance	0.0148982	0.013995733
Observations	10	10
Pearson Correlation	0.3348692	
Hypothesized Mean Difference	0	
df	9	
t Stat	-4.6551379	
P(T<=t) one-tail	0.0005967	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.0011934	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	Cognitive	*Visual*
Mean	0.7437	0.6319
Variance	0.0148982	0.011138322
Observations	10	10
Pearson Correlation	0.356141	
Hypothesized Mean Difference	0	
df	9	
t Stat	2.7226968	
P(T<=t) one-tail	0.0117519	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.0235038	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	Communication	*FMC*
Mean	0.6105	0.8713
Variance	0.0134785	0.015527344
Observations	10	10
Pearson Correlation	0.3329371	
Hypothesized Mean Difference	0	
df	9	
t Stat	-5.9253075	
P(T<=t) one-tail	0.000111	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.000222	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	Communication	*FMD*
Mean	0.6105	0.7419
Variance	0.0134785	0.013370322
Observations	10	10
Pearson Correlation	0.03456	
Hypothesized Mean Difference	0	

df	9	
t Stat	-2.5808933	
P(T<=t) one-tail	0.0148266	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.0296531	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	Communication	*GMH*
Mean	0.6105	0.5
Variance	0.0134785	0.277777778
Observations	10	10
Pearson Correlation	0.5892542	
Hypothesized Mean Difference	0	
df	9	
t Stat	0.7464425	
P(T<=t) one-tail	0.2372231	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.4744462	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	Communication	*GML*
Mean	0.6105	0.9478
Variance	0.0134785	0.013995733
Observations	10	10
Pearson Correlation	0.4009153	
Hypothesized Mean Difference	0	
df	9	
t Stat	-8.313496	
P(T<=t) one-tail	8.13E-06	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	1.626E-05	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	Communication	*Visual*
Mean	0.6105	0.6319
Variance	0.0134785	0.011138322
Observations	10	10
Pearson Correlation	0.5094537	
Hypothesized Mean Difference	0	
df	9	
t Stat	-0.6143825	
P(T<=t) one-tail	0.2770872	

t Critical one-tail	1.8331139
P(T<=t) two-tail	0.5541743
t Critical two-tail	2.2621589

t-Test: Paired Two Sample for Means

	FMC	*FMD*
Mean	0.8713	0.7419
Variance	0.0155273	0.013370322
Observations	10	10
Pearson Correlation	0.8563395	
Hypothesized Mean Difference	0	
df	9	
t Stat	6.2987286	
P(T<=t) one-tail	7.06E-05	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.0001412	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	FMC	*GMH*
Mean	0.8713	0.5
Variance	0.0155273	0.277777778
Observations	10	10
Pearson Correlation	0.1649547	
Hypothesized Mean Difference	0	
df	9	
t Stat	2.2528347	
P(T<=t) one-tail	0.0253838	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.0507676	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	FMC	*GML*
Mean	0.8713	0.9478
Variance	0.0155273	0.013995733
Observations	10	10
Pearson Correlation	-0.0623961	
Hypothesized Mean Difference	0	
df	9	
t Stat	-1.3660121	
P(T<=t) one-tail	0.1025466	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.2050932	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	FMC	Visual
Mean	0.8713	0.6319
Variance	0.0155273	0.011138322
Observations	10	10
Pearson Correlation	0.4024479	
Hypothesized Mean Difference	0	
df	9	
t Stat	5.9700026	
P(T<=t) one-tail	0.0001051	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.0002101	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	FMD	GMH
Mean	0.7419	0.5
Variance	0.0133703	0.277777778
Observations	10	10
Pearson Correlation	-0.1248902	
Hypothesized Mean Difference	0	
df	9	
t Stat	1.3820143	
P(T<=t) one-tail	0.1001503	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.2003006	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	FMD	GML
Mean	0.7419	0.9478
Variance	0.0133703	0.013995733
Observations	10	10
Pearson Correlation	-0.074964	
Hypothesized Mean Difference	0	
df	9	
t Stat	-3.7962713	
P(T<=t) one-tail	0.0021208	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.0042416	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	FMD	Visual
Mean	0.7419	0.6319
Variance	0.0133703	0.011138322
Observations	10	10

Pearson Correlation	0.2476987	
Hypothesized Mean Difference	0	
df	9	
t Stat	2.5600016	
P(T<=t) one-tail	0.0153435	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.030687	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	GMH	*GML*
Mean	0.5	0.9478
Variance	0.2777778	0.013995733
Observations	10	10
Pearson Correlation	0.4847076	
Hypothesized Mean Difference	0	
df	9	
t Stat	-2.9442114	
P(T<=t) one-tail	0.0081871	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.0163743	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	GMH	*Visual*
Mean	0.5	0.6319
Variance	0.2777778	0.011138322
Observations	10	10
Pearson Correlation	0.332593	
Hypothesized Mean Difference	0	
df	9	
t Stat	-0.8310303	
P(T<=t) one-tail	0.2137262	
t Critical one-tail	1.8331139	
P(T<=t) two-tail	0.4274525	
t Critical two-tail	2.2621589	

t-Test: Paired Two Sample for Means

	GML	*Visual*
Mean	0.9478	0.6319
Variance	0.0139957	0.011138322
Observations	10	10
Pearson Correlation	0.3947389	
Hypothesized Mean Difference	0	
df	9	
t Stat	8.0822214	
P(T<=t) one-tail	1.02E-05	
t Critical one-tail	1.8331139	

P(T<=t) two-tail	2.04E-05
t Critical two-tail	2.2621589

Team	Task	MOPP level	Error	Severity	Weighted error	Error Freq.	MOPP level
1	CPR1	4	did not check for bleeding	8	8	1	4
	CPR2	0	did not check for bleeding	8	8	1	0
	SIM1	4	did not hold head continuously	7			
			put c-collar on after patient strapped onto backboard	5			
			did not check PMS	1			
			did not check PMS	1	14	4	4
	SIM2	0	did not hold head continuously	7			
			did not check for bleeding	8			
			did not check PMS	1			
			did not check PMS	1	17	4	0
2	CPR1	0	did not check for bleeding	8	8	1	0
	CPR2	4	did not check for bleeding	8			
			CPR on bed	5	13	2	4
	SIM1	0	did not check for breathing	10	10	1	0
	SIM2	4	did not check for bleeding	8	8	1	4
3	CPR1	4	held victim during seizure	10	10	1	4
	CPR2	0	CPR on bed	5			
			did not check for bleeding	8	13	2	0
	SIM1	4	did not check PMS	1			
			did not check PMS	1	2	2	4
	SIM2	0	did not check for bleeding	8	8	1	0
4	CPR1	0	did not check for bleeding	8	8	1	0
	CPR2	4	CPR on bed	5			
			did not check for bleeding	8			
			did not check breathing	10	23	3	4
	SIM1	0	only checked pulse in wrist	1	1	1	0
	SIM2	4	did not check for bleeding	8			
			did not check PMS	1			
			did not check PMS	1			
			backboarded while standing	7	17	4	4
5	CPR1	0	did not check for bleeding	8			
			held victim during seizure	10	18	2	0
	CPR2	4	did not check for bleeding	8	8	1	4
	SIM1	4	did not check breathing	10			
			did not check breathing	10			
			did not check PMS	1			
			did not check PMS	1	22	4	4
	SIM2	0	did not check for bleeding	8			
			did not check PMS	1			
			did not check PMS	1			
			no pads beside head	2			
			backboarded while standing	5	17	5	0

VITA

Nancy L. Grugle

Nancy Grugle received a B.S. degree in Industrial and Manufacturing Systems Engineering from Ohio University in 1999. She is a graduate student in Industrial and Systems Engineering (human factors engineering option) at Virginia Polytechnic Institute and State University and will receive an M.S. in May 2001. Nancy worked as an industrial engineer for the Army Research Laboratory during the summer of 2000. She worked on modeling team performance and conducted research on measuring team performance. She is currently a member of the Human Factors and Ergonomics Society as well as the Institute of Industrial Engineers.