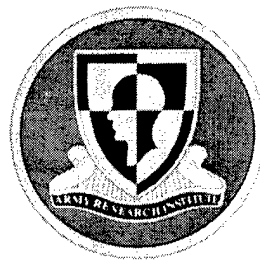


**Special Report 55**

**U.S. ARMY RESEARCH INSTITUTE  
PROGRAM IN BASIC RESEARCH  
2002-2003**



**Research and Advanced Concepts Office  
(RACO)**

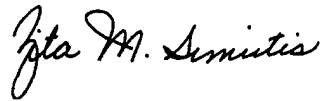
**October 2002**

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**20030103 039**

## FOREWORD

The purpose of this document is to communicate the annual progress for each individual research project in the Research and Advanced Concepts Office (RACO) basic research program at the United States Army Research Institute for the Behavioral and Social Sciences (ARI). The summaries contained herein are written by the scientists who are performing the work and provide a snapshot of their continuing efforts. In addition, RACO conducts a more detailed in-progress review of each project each year. If successful, the projects within RACO's basic research program will lay the foundations for many of ARI's future applied behavioral research efforts. These summaries serve as guideposts for ensuring that our basic research results transition to ARI's applied research programs.



Zita M. Simutis  
Acting Director

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## **THE BASIC RESEARCH PROGRAM: IDENTIFYING NEW AND PROMISING TECHNOLOGIES**

The Research and Advanced Concepts Office (RACO) manages ARI's basic research program that focuses on combinations of the personnel, leadership, and training requirements of the future. The basic research program is a critical link between the world of behavioral science and the military community. Searching out and advancing the state-of-the-art methods, theories and findings in behavioral science, encouraging projects most likely to contribute generalizable scientific principles and new knowledge, and supporting those efforts that have potential military relevance and likelihood of leading to applied behavioral technology are RACO's key research goals.

Universities conduct most of the basic research program. RACO maintains close contact with ARI's applied researchers and other relevant agencies within the Army. These contacts help to define issues that require fundamental research, and facilitate the transition of basic research results to applied programs for eventual use by the operational Army.

In RACO's contract programs, a Broad Agency Announcement (BAA) is issued each year to solicit both concept papers and formal proposals relating to the announced program areas. In a given year, the BAA highlights the research objectives of special interest, and provides an open call for proposals.

On the following pages, the reader will find summaries of current, on-going RACO contracts ranging over the period 1998 - 2002. There are three current RACO program objectives, each of which will be discussed in detail below. They are as follows:

1. Provide fundamental knowledge to improve training in complex, digital environments,
2. Provide fundamental knowledge to improve leader assessment and accelerate leader development,
3. Provide fundamental knowledge for identifying and measuring the attributes and skills that are critical to soldier recruiting, performance, and retention in the transforming Army.

### *Training for Speed in Knowledge*

Basic research in this area focuses on developing concepts and methods for training complex tasks and for sustaining complex task performance. Assessing the cognitive impact of Objective Force technology requirements arising from digital systems, semi-automated systems, and robotic systems, on training requirements is also part of this process. A new effort in this area seeks to understand the impact of the voluminous multi-modal data on performance and how individuals and teams might be trained to integrate and use such rapidly presented data. We seek to identify unique training principles and methods for improving interpersonal skills and team adaptability and performance. The expected outcome is applied research testing the principles and methods produced in this work package in Army training environments. The models and theories produced should be useful in accounting for individual differences in training and facilitating practical, individualized, adaptive training methods. These advances will translate into improved training methods in a wide range of tasks.

### Assessing and Improving Leader Skills

Commensurate with the Objective Force requirements for rapidly developing adaptable, flexible leaders, the basic research program in leader development is directed toward providing concepts and methods for accelerating leader development and understanding and developing leader adaptability and flexibility in a manner that can be tested in the applied environment. One of our major efforts in this area is using Sternberg's theory of practical intelligence to develop new techniques for acquiring experience-based, tacit knowledge as a means for rapidly developing effective military leaders. We are also committed to discovering and testing the basic cognitive principles that underlie effective leader-team performance. Understanding the dynamics of small group leadership in face-to-face and distributed team environments is a key aspect current basic research program in leadership. For example, one of our research projects seeks to develop leadership techniques that foster interaction, communication, and trust in electronic environments. Another examines distant leadership behaviors under the stress of performing in a metropolitan hospital shock trauma center.

### Personnel Issues for the New Century

Identifying and measuring the aptitudes and skills that are unique to the human performance requirements of the Objective Force is a major theme of this basic research effort. As part of this process, we seek to devise methods that assess persistency and dependability, describe how these attributes develop, and measure their contribution to performance and job tenure. For example, we have begun a new effort to assess individual adaptability and flexibility as aptitudes that can be measured across job domains. Exploring the sociological and psychological factors that could influence recruitment, retention, and performance is part of this work package as well. Several sociological research efforts seek to understand how various social structures, such as the family, and population demographics influence Army performance. In another research effort we are investigating the conditions under which turnover hinders or helps team performance. Although turnover can be harmful, for example, when a team loses a productive member and must expend time and energy training a replacement; turnover can also be helpful, as when a team loses an unproductive member and gains a replacement with valuable knowledge. We anticipate that results from this research will make an important contribution to understanding and improving organizational effectiveness.

This document provides a listing and brief synopsis of ongoing and recently completed research efforts. Project listings are organized into the three aforementioned research objectives. It is important to note, however, that this program is but one of many programs for which RACO has responsibility. Other programs in RACO include:

- Small Business Innovative Research (SBIR) Program,
- Small Business Technology Transfer (STTR) Program,
- International Behavioral Science and Technology Watch,
- Graduate student apprenticeship program - Consortium Research Fellows Program – with the Consortium of Metropolitan Washington Universities,
- Outreach efforts to Historically Black Colleges and Universities (HBCUs) and Minority Institutions (MIs), and
- Research support in behavioral science for the U.S. Military Academy.

Additional information about reports from these research efforts is available upon request.

## **RACO RESEARCH OBJECTIVE #1:**

*Provide fundamental knowledge to improve training in complex, digital environments.*

Research under this objective develops concepts and methods for training complex tasks and sustaining complex task performance. The focus is on understanding the cognitive impact of Objective Force technology on training requirements, the impact of voluminous multi-modal data on performance, and developing methods for improving the interpersonal and cognitive skills that affect team performance.

# **Optimizing the Speed, Durability, and Transferability of Training**

**Contract #:** DASW01-99-K-0002  
**Institution:** University of Colorado

**Contract Dates:** 8/1/99 – 7/31/02  
**PIs:** Alice F. Healy & Lyle E. Bourne, Jr.

## **Scientific Objectives**

The U. S. Army spends much time and many resources in training its personnel. Training is essential because recruits cannot be expected to come equipped with the military knowledge and skills they will need in the field. But training is costly, so it is important to ensure that it be accomplished as quickly and efficiently as possible. However, increasing training speed should not be the only, or even the most important, consideration. If soldiers successfully learn how to perform a task during training, but then forget how to perform it when needed, training has clearly been inadequate. Passing a test at the end of training does not guarantee later success in the field. Training needs to be durable as well as efficient. But even durable training cannot guarantee that learned knowledge and skills will be applied successfully to situations different from those encountered during training. Training circumstances can rarely capture the full set of circumstances under which tasks are encountered in the field. Therefore, it is essential that training be transferable as well as durable. It is the aim of our research program to develop principles that separately optimize the three major aspects of training: (1) speed/efficiency, (2) durability/long-term retention, and (3) transferability or generalizability to new situations.

## **Approach**

Although many of our studies have overlapping goals, for present paper we have divided them into three major groups. The first group is principally concerned with managing factual overload, rapidly presented information, stress, frustration, and fatigue, with an emphasis on tasks involving perceptual and motor processing. The second group addresses the comprehension of verbal and spatial information. The last group primarily considers optimizing the balance of the three major aspects of training.

Studies on managing factual overload, rapidly presented information, stress, frustration, and fatigue focus on the following four issues: (1) handling factual overload, (2) dealing with rapidly presented information, (3) initiating and executing responses under stress and frustration, and (4) initiating and executing response components under fatigue produced by prolonged work.

Studies on comprehension of verbal and spatial information focus on the following four issues: (1) how the mental representation of space affects the comprehension of navigation directions within that space, (2) the retention and transfer of the skills involved in comprehending navigation directions, (3) the relationship between the verbal and spatial representations of navigation directions, and (4) the effects of overload on the comprehension of navigation instructions.

Studies on balancing the three major aspects of training focus on the following four issues: (1) the sources of specificity during training and transfer, (2) variations in contextual interference and task difficulty as a means to promote durability and transferability of training, (3) types of strategies and strategy transitions during training, retention, and transfer, and (4) seeding the knowledge base with a minimal set of facts.



## Progress

### Managing factual overload, rapidly presented information, stress, frustration, and fatigue

We studied response execution in a motor coordination task involving various forms of hand-eye incompatibility. We found that practice with a given form of incompatibility led to large improvements during training and high durability across a 1-week delay, but minimal transfer from one type of incompatibility to another. Even when subjects practiced with a condition that combined up-down and right-left incompatibility, there was no transfer to performance with a condition that involved only one of the types of incompatibility. Also, training with the more difficult right-left incompatibility did not aid in performance with the simpler up-down incompatibility. The current implication for military training is that when eye-hand coordination is involved in a skill, for practice to be effective, specific forms of hand-eye incompatibility must be trained in the particular way that will be encountered subsequently in the field. Our future research on this topic will be aimed at developing methods to overcome this specificity, to enable trainees to adapt to new conditions not encountered during practice.

### Comprehension of verbal and spatial information

We have developed a laboratory analog of communication between air traffic controllers and pilots. In this task, participants are given instructions like those given by air traffic controllers. Sometimes they were required to repeat the instructions aloud, as pilots are expected to do, and then follow the directions to navigate in the space displayed on the computer. Using this analog, we completed an experiment in which we studied the effects of presentation format and readback on the comprehension and execution of navigation instructions. As in previous studies, we found a large drop in performance between messages with three and messages with four commands, bolstering our earlier recommendation to limit navigational instructions to three commands if possible. In addition, as in a previous study, we found that requiring subjects to readback navigation instructions before executing them led to a large decrement in their ability to follow the instructions. However, we also found that reducing the readback requirement by telling subjects to readback only the crucial words greatly lessened this decrement. Because the advantage for reduced readback may be attributed in part to a change in the visual scanning strategy, we only tentatively make the recommendation for pilots and others receiving navigation instructions auditorily to reduce the length of their readback. Such reduction in readback will still permit verification but will minimize the cost of output interference. Although there were no overall differences between simultaneous and sequential presentation of the commands, with simultaneous presentation, there was a greater decline in performance as command position increased, suggesting that subjects did not optimally allocate their attention. Therefore, we recommend that individuals who must follow navigation instructions be given additional training both in telescoping their readback and in efficiently allocating their attention to each command of the instructions.

### Optimizing the balance of training aspects

We studied variations in contextual interference and task difficulty as a means to promote durability and transferability of training. We found that increasing task difficulty by different manipulations during study slowed down learning but seemed to aid transfer to a new task as well as long-term retention of the original task. However, the long-term benefit was limited to the specific trained items and did not extend to other items, even those from the same category as the trained ones. The implication for training is that enhancing the difficulty of training exercises may lead to improved retention and transfer to new tasks but not to new items.

In concept-learning tasks, participants sometimes adopt an initial strategy of learning arbitrary associations between items and responses, but later make a transition to rule-based performance once the concept is discovered. In mental arithmetic tasks, participants often show a transition from initial rule-based performance to memory-based performance after extensive practice. We have demonstrated both types of transitions within the same binary classification task. We found that both rule difficulty and rule salience determine the strategy that subjects eventually adopt with training on a given task. In a new experiment, where the same simple rule was used in all tasks, the strategy adopted was rule-based or instance-based, depending on the salience of the rule. These findings imply that, to optimize performance, trainers need to be aware of both the salience and the difficulty of the operative rule for responding in any given task. No matter how simple it is, when a rule is not obvious learners may adopt a strategy in which they memorize specific instances rather than use the underlying rule.

### **Contributions to Basic Science**

The many research directions we are pursuing address a diverse set of issues but have three primary goals. First, we have initiated an intensive examination of extraneous variables (including factual overload, rapid presentation of information, stress, frustration, and fatigue) that might adversely affect training. Understanding the impact of these variables will enable us to develop procedures to counteract their deleterious effects. Second, we have commenced a series of studies that could lead to the development of training routines for optimizing the comprehension of both verbal and spatial information. Third, we have started research concerned with optimizing the relationship between all three major aspects of training--its speed, durability, and transferability. These studies share a common analytical and experimental methodological approach and the common theoretical goal of understanding the psychological principles underlying the acquisition, retention, and generalization of knowledge and skills.

### **Potential Applications**

These studies also share the common applied goal to improve the training of military personnel such that knowledge and skills will be acquired more quickly, yet still be accessible across long delay intervals without practice as well as adaptable to new situations outside the training environment. The balance of the three aspects of training (speed, durability, and transferability) is not necessarily fixed across tasks or even within a given task. Instead, the balance may depend on a variety of external factors that can change from time to time, such as stress, frustration, fatigue, speed of information presentation, and information load. Variations in any of these external factors can affect the interaction of the speed, durability, and transferability of training. Hence, our research also examines these three aspects of training under various conditions of stress, frustration, fatigue, speed of information presentation, and information load. The information gathered from this research will help in the design of training programs that allow the trainee to contend with external conditions in the field that are often unpredictable and could adversely influence performance if not properly managed.

## **Understanding aspects of individual and collaborative skill acquisition in face-to-face and distance training situations**

**Contract #:** DASW01-01-K0003  
**Institution:** New Mexico State University

**Contract Date:** 9/1/01-8/31/04  
**PI:** Adrienne Y. Lee  
**Co-PIs:** Douglas Gillan & Nancy Cooke

### **Scientific Objectives**

In recent years, the advancement of military technology has resulted in a need to acquire and maintain highly complex skills to effectively use that technology (Barry & Runyan, 1995). Consequently, the demand for ongoing innovations, including distance training, has increased. Distance training has been shown to be extremely cost effective and has produced similar learning outcomes. Although extensive research on distance learning exists, few studies have focused on group (collaborative) distance training delivered by Internet/web-based technologies.

A parallel development has occurred in the area of team training. Even though group (collaborative) learning has been the focus of many studies (Slavin, 1996) and progress has been made on knowledge measurement at the individual level, the measurement of team knowledge and team cognition is still in its infancy (Cooke, Salas, Cannon-Bowers & Stout, 2000). Thus, research on how to improve team distance learning could contribute significantly to the field.

The questions being addressed in our research include: (1) Do co-located teams train more quickly than distributed teams? (2) When tested in the same situation (e.g., co-located training and testing and distributed training and testing), will co-located teams perform the transfer mission more accurately and learn more quickly than distributed teams? (3) Will the results be different when teams are asked to learn a new transfer mission in a different situation (e.g., co-located learning to distributed testing and distributed learning to co-located testing)? Additionally, in a follow-up experiment, we will be adding training based upon observations and data collected in experiment 1. Thus, an additional question includes whether this added training improves performance for teams learning in a distributed manner.

### **Approach**

This research examines the acquisition of complex skills by teams either training face-to-face (co-located) or remotely (distance/distributed training). In face-to-face training, team members are co-located and interactions are encouraged through the physical arrangement of the computers (training systems). In distance training, team members located at different locations from the instructor and each other. Two experiments are being conducted. In the first experiment, we are testing teams in the same or different training situation to assess the degree of team-relevant skills transfer. The second experiment will examine task-related transfer when varying the test task relative to the training task. In addition, if distance training is not better than face-to-face training, then the second experiment will draw from the first experiment to improve distance learning.

### **Progress**

We have designed the materials and experimental protocol for the first experiment. We have created a listing of specified changes to the equipment/computers and these changes have been delivered to Sandia Research for implementation. We have determined the details of the experimental protocol and what test instruments need to be delivered by the experimenters. These changes will be made to the experimenter's manual. Further, student experimenters have

been trained and are participating in the current experiment as practice for running subjects on the first experiment. We anticipate that we will start to run subjects for this experiment by the end of March.

### **Contributions to Basic Science**

This research lies at the intersection of two current issues in training – team cognition and distance learning. Although extensive research has been performed on distance and group (collaborative) learning, few studies have focused on collaborative distance learning and only recently have studies focused on team cognition. Even fewer studies have been performed on team distance learning (where team members are located at a distance from each other and the instructor). Thus, this research has implications for the advancement of scientific knowledge concerning team learning, distance learning and team distance learning. It will also provide specific advice about enhancing these three types of learning.

### **Potential Applications**

A significant amount of the success in military performance is due to team performance, rather than just individual performance. Therefore, providing effective team training is critical. Because Internet technology has improved dramatically over the last decade, distance learning that includes high quality audio and visual transmission is possible. Web-based instruction provides an opportunity to cut costs and deliver training to individuals at remote locations before they must either learn together as a team or perform some team task. Because remote training can be cost effective and recent advances in Internet/web-based technology allow for interactivity, research on how to improve team distance learning will be beneficial for the Army. Further, in today's military, teams of individuals who may never have met each other, who are not necessarily sitting together in the same briefing room side-by-side on the same battlefield, and who may only communicate and share information via communication and computer technologies perform many military tasks. Indeed, the entire nature of warfare has taken on a "network centric" characteristic (Wilson, 2000) in which the battlefield is dispersed not only over terrain but also over the Internet. Thus, these studies will provide a better understanding of team learning (cognition and performance) that can be used to improve both face-to-face and distance team training.

## **The Effect of Team Training on Team Cohesion**

**Contract #:** DASW01-00-K-0013  
**Institution:** Old Dominion University

**Contract Dates:** 8/14/01-10/13/02  
**PI Name:** Robert M. McIntyre

### **Scientific Objections**

The objectives of this research are (a) to empirically examine the effects of team process training on team cohesiveness, (b) to empirically investigate the relationship between team cohesiveness and team performance. The team process training was based on a model of team processes developed by Dickinson and McIntyre (1997).

### **Approach**

We have approached this research by applying two different paradigms. The first involves the use of a standard pre-post control group study with randomization of teams to either a placebo or a team training condition. The dependent variables investigated in this first approach were the components of cohesion as measured by the System for the Multiple Level Observation of Group (SYMLOG) (Bales & Cohen, 1980). A four-hour training program based on the team process model was conducted with the experimental group. A manipulation check on the team training was carried out by applying a measure of the seven team processes developed by Rosenstein (1994). Results indicated that cohesion was greater immediately after training as well as one month after the training program had ended when compared to the control group. This suggested that team process training can contribute to greater levels of team cohesion.

The second paradigm is based on a true time series design. It examines (a) team cohesion as a function of time, (b) the effects of team training on team cohesion, (c) the decay of team cohesion over time, and (d) the time-dependent relationship between team cohesion and team performance. "Time dependency" refers to the tendency for time series data to be autocorrelated. The use of the time series design provides the basis for answering multiple questions simultaneously including questions about team cohesiveness, team training, and team performance in ways that have not been used in the past. In addition, we are examining a set of variables that may impact the relationships between team training, team performance, and team cohesiveness. These variables include affect of team members (positive and negative), team members' perceptions of task load, team members' perceptions of "life load," diversity of team members vis a vis demographics, and diversity of team members vis a vis academic achievement.

In the time series experiment, 11 teams of students (each consisting of five or six students) participated over a period of 15 weeks in a course designed around the team concept. That is, during the course students learned by self-study and through team exercises. Teams met three times per week. Students worked on a multi-part class assignment for 50 minutes. This assignment was scored and is treated as the team performance measurement. In addition, at the end of each session, team members complete a series of questionnaires designed to assess cohesiveness, affect, and perceived work load.

Team training was provided during the eighth week of the course. This training was based on the Dickinson-McIntyre team process model. The format of the training included lecture, modeling, practice, and feedback. It was hypothesized that team performance and team cohesion would improve as a function of team training. To assess the effect, a separate time series analysis was carried out for each team.

### **Progress**

The first experiment (involving the use of the pre-post training design) was completed in 2001. We presented the results of this study at the 17<sup>th</sup> annual conference of the Society for Industrial and Organizational Psychology.

The second three-phase study was carried out within the context of three Masters theses. The breakdown into three phases was implemented because of the complexity and difficulty of the analyses. Two of the three are complete. In the first, the results indicated that team training positively affected cohesiveness. However, training did not affect team performance. In the second study, a variable set of results were found. For certain teams, affect-pertinent variables affected cohesiveness. However, no performance predictors were found.

These somewhat puzzling results led us to examine the nature of our performance measure and the observations we had regarding how the student learning teams approached the team task. The learning teams did not like the course structure. Student teams broke the team tasks into disjunctive parts, thereby making the task much less team-dependent than planned. In addition, we noted that the performance measure may suffer from validity problems in that course material changed each week which may have resulted in exercises that were not uniformly difficult. To address these issues and to explore other more complex models, the third phase of the research is being carried out. It will be completed as a part of Hope Hanner's Masters thesis before the end of August. The final report will be written and results presented to ARI in October.

In addition to the work described above, the research team at ODU has carried out several additional endeavors. First, the content validity of the training program was established to ensure it was representative of the material that should be presented in a team training program. Second, we designed a prototype of an interactive computer-assisted team training device as a proof of concept. Third, we started to revise the team training program for the next phase of our research. Fourth, the director of the ROTC students at ODU was contacted in order to elicit his support in future research. We plan to continue our research program and to include a stronger emphasis on leadership in team training. Thus, although the Dickinson-McIntyre process model includes leadership as a critical component, it will receive much greater emphasis in the future. Fifth, we are searching for team tasks on which to study team performance. Within the context of the current contract, it is impossible to purchase team tasks. However, there are computer-based tasks (such as the microworld used for training FAA personnel) that would be both realistic and practical team training research tasks. We hope to access such tasks in the future.

### **Contributions To Basic Science**

The first study implied that model-driven team training affected team performance and the effect persisted over time. Therefore, the main contribution of this study is the finding that when one uses a coherent and data-based conception of teamwork, one can expect to find increased cohesion.

The second study is much more complex. This three-phase research design is intended to address the following: (a) how a team becomes cohesive, (b) whether cohesion covaries over time with performance (taking into account autocorrelation of data), (c) the nature of the effect of team training on team performance and team cohesiveness over time, (d) the effect of workload

on cohesiveness and performance, and (e) the effect of affective state on team training, cohesion, and performance.

The examination of team performance and team processes *over time* is an important and unexplored area. Ultimately, it will have a major bearing on understanding team leadership. At present, the contributions are still unclear from this complex study. For example, although certain relationships were found in phase one and two of this study, these were not consistent across teams. It is unclear how to deal with the inconsistency. Classical science may suggest that if a phenomenon is inconsistent, it is not reliable, and therefore is unreal. However, we are not quick to draw such a conclusion. Perhaps what basic science will learn from our research is that certain relationships exist for some teams and not for others. This points to other basic questions that beg to be answered. The third-phase study will address some of these questions.

### **Potential Applications**

Our research provides a framework for developing effective team training systems. In fact, our vision is that from the earliest stages of socialization a soldier may begin to learn to be a team member through the perspective of the teamwork process model. Admittedly, this vision goes beyond the current findings. However, the results thus far do suggest that learning about teamwork can provide the basis for making certain behavioral changes that will lead to increased cohesiveness. We believe that if a systematic training program were developed to provide more modeling, practice, and feedback, it would prove to be an important tool for increasing cohesiveness. Further, although our data are still not supportive of the following statement (due to unforeseen measurement problems in the second study), we continue to hypothesize that with the proper task, the appropriate population, and the appropriate team performance measure, team process training will lead to improved performance and cohesion. In effect, the studies that we carried out, with a relatively small amount of resources, serve as a proof of concept that team process training can be implemented and can lead to positive outcomes for the field.

## **Working Memory Influences on Long-Term Memory and Comprehension**

**Contract #:** DASW01-99-K-0001  
**Institution:** University of Notre Dame

**Contract Dates:** 06/15/99-06/14/02  
**PI:** Gabriel A. Radvansky

### **Scientific Objectives**

An important need of a large organization, such as the Army, is that complex sets of information about events in the world be readily understood by the people entrusted with that information. This would include the ability to understand descriptions of events occurring in some other part of the world and the need to understand and accurately remember instructions about how to perform under various circumstances. To understand information well, a person must be able to successfully comprehend the nature of the events that are being referred to by the descriptions that have been provided. The simple retention of a collection of individual pieces of information is insufficient. A person must be able to properly relate that information to external circumstances. This project has two primary goals. First, to assess how an individual's cognitive abilities can be used to predict future performance on comprehension and long-term memory tasks. Second, to develop methods of training that are tailor-made to an individual's weaknesses. Specifically, this project focuses on how working memory (that portion of cognition where information is actively manipulated) influences higher-level comprehension and the long-term memories that result from this comprehension. These long-term memories are often called mental models because they are mental simulations of sets of circumstances that could exist in the world. This project assesses the degree to which successful processing of mental models is predicted by traditional measures of cognitive ability or whether this processing can be better predicted by measures aimed more directly at how these representations are created and retrieved. Several studies are being conducted to examine how various ability tests can be used to predict future performance in processing event and situation information. This is important because our knowledge about events in the world relies more on the mental models we create than on lower level representations, such as propositional codes. Mental models are a means of capturing and coordinating complex sets of information about circumstances and events.

### **Approach**

This project involves a series of experimental and correlational studies that examine individual differences in complex information understanding and one's subsequent memory for that information. For the project, we utilize various individual difference measures of cognitive ability as well as evaluate performance on various language comprehension and memory retrieval tasks that assess complex information processing about events and episodes. The cognitive ability measures are designed to quantify a person's basic cognitive skills. In comparison, the performance measures are designed to assess the actual processing of complex sets of information both during the actual process of understanding, as well as later, when individuals must remember needed information. These performance measures cover a range of mental tasks including language comprehension, long-term memory, and logical reasoning. The data for this project are being collected both at the University of Notre Dame and Indiana University at South Bend to gain a wider range of abilities.



### **Progress**

We have completed data collection for two studies that have explored the accuracy of traditional measures of working memory and how well they predict performance on various established mental model measures. Results indicate that while working memory measures do predict a few aspects of performance, they are limited in their ability to predict future performance. In many cases, other measures of complex event processing were better predictors of future performance. The data from this research has been reported in four papers. One is in press at the journal *Memory & Cognition* where it will be the lead article, one is under review at the *Quarterly Journal of Experimental Psychology*, and one is under review at the *American Journal of Psychology*. The fourth manuscript is in preparation.

Currently, we are collecting data for a series of experiments aimed at investigating how people update their understanding of events. In particular, our focus is on how people update spatial and temporal information. Specifically, when there has been a shift in space or time, how efficient are people at making this shift? Also, when people have problems making this shift, what is the nature of the difficulty? This research will allow us to gain greater insight into those aspects of comprehension and event memory that are difficult for people versus those for which people show a fair amount of competence. This information will allow us to target programs designed to increase a person's ability to comprehend ongoing information about events.

Additionally, we are continuing to develop a computer simulation of mental model construction and use. To constrain its initial development, we have limited the model to solving categorical logic problems. To date, the computer model has been successful in predicting how accurately and quickly people are able to understand a description of a state of affairs in the world and draw the appropriate inferences from that information. We will continue to expand this model to contain other sorts of event knowledge. This model is a very exciting aspect of our research because it has the potential to identify, with a high degree of precision, the specific nature of the difficulties people have in constructing mental models and making inferences based on their understanding of the world.

Currently, we are preparing a data collection for a study which will investigate the model's ability to identify an individual's comprehension deficits, create a training program specifically targeting those deficits, and assess the influence of that training both immediately and over the long term. This proactive approach will help prevent people from spending time and energy training on cognitive tasks at which they are already skilled. Instead, efforts can be targeted to an individual's specific deficiencies.

### **Contributions To Basic Science**

This project will provide us with a more advanced understanding of working memory capacity and processes as well as the role these play in various aspects of comprehension and long-term memory. This research follows and integrates long-time traditions in each of these areas of cognition. Furthermore, a better understanding will be gained of how people comprehend, monitor, and remember changes in events and situations in the world based on the information they receive. Lastly, we are developing a more precise computer model of event comprehension and memory that will allow for a much more specific prediction of a given individual's performance. Because we are interested in information involving complex sets of descriptions about events, how that information is processed, and how to identify people who are good or poor at this sort of processing, this project is highly relevant for the U.S. Army.

### **Potential Applications**

The potential applications of this research for the Army are in the areas of training assessment and curriculum. If validated, the assessment battery measuring complex information comprehension and memory may be used to identify individuals who are better at processing complex information and potentially, to identify an individual's processing weaknesses. The training guidelines that we hope to develop will be designed to target those aspects of event comprehension and memory that are weak. These assessment tools, coupled with targeted training, can serve to minimize the amount of time needed to increase a person's ability to comprehend and remember event information.

# Exploring the Interaction of Implicit and Explicit Processes to Facilitate Individual Skill Learning

**Contract #:** DASW01-00-K-0012  
**Institution:** University of Missouri-Columbia

**Contract dates:** 9/00-8/03  
**PI:** Ron Sun  
**Co-PI:** Robert Mathews

## Scientific Objectives

The scientific objectives of this research are (1) To experimentally investigate the interaction between implicit and explicit processes in skill learning (which is contrary to the common tendency of studying each type in isolation) with the goal of enhancing learning through knowledge of the interaction between implicit and explicit processes; (2) To develop computational models and theories of human skill learning that emphasize the interaction of these two types of processes, which may be of use in structuring and optimizing training, on the basis of our experimental and simulation results.

## Approach

The current work develops an integrative approach for skill learning that takes into account both implicit and explicit processes. Specifically, we focus on the interaction between the two types of processes and the various effects of this interaction on improving or hampering learning (e.g., the synergy effects; Mathews et al 1989, Sun 1997, Sun et al 2001). In particular, we will focus on a bottom-up approach (first learning implicit knowledge and then explicit knowledge on its basis).

A computational model, CLARION, which is markedly different from other existing cognitive architectures, will be further developed in this work to simulate and capture a range of quantitative data that are related to the interaction. This will help us to predict (and optimize) learning processes. We will carry out experiments in the domain of process control tasks, as well as the domains of some other tasks, and generate new data that further explicate the interaction between implicit and explicit processes. These anticipated outcomes (data, models, and theories) will provide a new perspective on skill learning. Our models and theories will be useful to better understand skill learning and how to help improve learning processes. Our models and theories may also be useful in understanding individual differences in training and in developing individualized, adaptive training.

## Progress

We further developed and enhanced the basic software that serves as our paradigm for the experiments. With the enhanced software, we completed 4 experiments and designed the 5th experiment to examine reflection with different types of hints. Results thus far suggest that reflection during or after practice on this task has little benefit. In fact, it sometimes interferes with learning. The interference effect appears to stem from slowing down bottom-level implicit learning rather than a direct influence of top-level learning (generating bad explicit rules). Evidence for this comes from the experiment completed last semester in which we demonstrated that reflecting about possible rules for the task was no more damaging to learning than simply predicting the next output level or even doing an unrelated task (generating sentences=20 containing specific words). Thus, without a hint about how to reflect, there are no benefits of explicit thinking. This task appears to be learned almost completely implicitly when no hints are provided. This is interesting given that learners are able to generate some valid rules. This

pattern of results suggests that valid rules emerge from bottom-up learning rather than a separate contribution of explicit (top-level) learning when no hint is provided.

Currently, we are running a large (16 cell) experiment exploring reflection with different types of hints. We have begun collecting this data. Additional model development has been accomplished. We enhanced the action rule mechanisms, including introducing utility and activation measures. The enhancement enables the calculation of response times in the model. We are also introducing non-action-centered representations to the model, which will further enhance the capability of the model. New simulation has been carried out with the enhanced model.

The enhancement enables us to account for top-down learning (learning that goes from explicit to implicit knowledge), in addition to accounting for bottom-up learning (learning that goes from implicit to explicit knowledge). We simulated some new human data sets related to skill acquisition, including human performance in learning Tower of Hanoi, letter counting (alphabetic arithmetic), and dynamic process control. These simulations will lead to new insight into skill acquisition processes.

We developed a framework and a model in which both top-down learning (learning that goes from explicit to implicit knowledge) and bottom-up learning (learning that goes from implicit to explicit knowledge) can be captured in a rather parsimonious way. Thus, both can be explored within a unified framework for understanding human skill acquisition.

Ron Sun and Bob Mathews co-organized a symposium at the 2001 Annual Conference of the Cognitive Science Society, on the interaction of implicit and explicit processes in cognition, which is also the main focus of our project. The symposium was well attended and received. Ron Sun published one conference paper on preliminary simulation results in COGSCI2001. Ron Sun also submitted two conference papers on some additional simulation results to COGSCI2002, which are under review now. Ron Sun published one journal paper in Neural Networks (co-authored with Antony Browne), another one in Cognitive Science (co-authored with Ed Merrill and Todd Peterson), and yet another in Cognitive Systems Research. He also published a book entitled: "Duality of the Mind."

### **Contribution to Basic Science**

Through our experiments, we will further explicate the interaction between implicit and explicit processes in cognition, which has not been focused on by previous research on human cognition (including cognitive skill acquisition) and should prove to be of significant interest to the scientific community. Our computational model, CLARION, which is markedly different from other existing cognitive architectures, will capture a wide range of quantitative data that are related to the implicit/explicit interaction, which will be of significant interest to the cognitive science community. Overall, our research results will provide a better theoretical perspective on human skill learning. In particular, our models and theories will be useful in improving the theoretical and practical understanding of individual skill learning through the analysis of the interaction between implicit and explicit processes.

### **Potential Applications**

Our anticipated outcomes (data, models, and theories) from this project will provide a more accurate picture of human skill acquisition. Our models and theories will be useful in taking into consideration individual differences in training and in developing practical individualized adaptive training methods. The theoretical advances will translate into improved training methods in a wide range of tasks. This project has just started and the application potentials will become even more evident as the project progresses.

## A Program for Training Sensemaking Skills

**Contract #:** 1435-01-01-CT-31161  
**Institution:** Klein Associates

**Contract Dates:** 6/18/01-6/17/04  
**PI:** Gary Klein

### Scientific Objectives

This research effort is comprised of three technical objectives:

Objective A: Determine the nature of 'sensemaking' as a process for developing situation awareness.

Several researchers have offered descriptions and models of situation awareness. Endsley (1995) describes three levels of situation awareness and suggests metrics for each level. Tenney, Adams, Pew, Huggins, and Rogers (1991) and Sarter and Woods (1991) offer more contextualized views of situation awareness. However, to our knowledge, no effort has undertaken the task of identifying and comprehending the *process* by which individuals develop situation awareness – how they distinguish between relevant and irrelevant information and situational cues, draw meaning from a set of cues offered by the environment, and incorporate their background knowledge into an assessment of the current situation. This is an attempt to unpack the process and nature of situational understanding and is distinct from describing or modeling the nature of situation awareness as a state. We are employing our experience studying higher-order cognitive functioning in naturalistic, real-world environments to unpack the process of situational understanding by using subject-matter experts in context.

Objective B: Determine the effect of information format on sensemaking.

As information technologies develop, it has become possible to present information in different formats. Where information once was shared only via textual reports and radio communications, it can now be transmitted as photographs, video clips, or other graphical representations. Our objective is to determine what effect cue presentation has on sensemaking. We will do this by presenting cues and information in two different formats. In the first version (presented in November 2001), information was presented using text and a map in paper-and-pencil format. The second version will be enhanced to include photographs, video, and a timeline presented via computer. By presenting information in different forms and comparing the ability of the participants to make sense of the information, we can draw conclusions as to the effect of information format on sensemaking. Effects will be examined in two ways. First, Cognitive Task Analysis interviews will be conducted with experts and novices in both presentation modes. This will allow us to study differences in expert and novice strategies and inferences. Second, we will also train novices using both presentation modes to determine the effect of training on their ability to develop better strategies and make sharper inferences.

Objective C: Examine techniques for hastening individuals' capabilities to comprehend ambiguous situations.

The third technical objective is to identify training interventions that can increase an individual's ability to make sense of a situation. We have conducted extensive research in the area of naturalistic decision making and have subsequently developed scenario-based training interventions intended to speed the acquisition of decision-making expertise (McCloskey, Lake, Pliske, & Klein, 1998). We anticipate experimenting with a similar technique aimed at boosting sensemaking skills. This methodology is called FOCUS – Framework for Observing and Comprehending Uncertain Situations.

FOCUS is conceptualized as follows: A situation or scenario stands at the center of the training. The student's goal is to make sense of the situation as it unfolds. In order to do so, FOCUS gradually and systematically provides pieces of information about the situation to the student – these may be situation reports or Intel reports at lower levels of fidelity or video clips and imagery at higher levels of fidelity. The student's task is to integrate the information into his/her mental picture. We believe from previous research that experienced operators will be able to make sense of the situation with fewer pieces of information, while less-experienced individuals will take longer to identify what is happening. The training intervention enables students to *practice* interpreting a situation based on information inputs and provides them with *feedback* on their interpretations via a window into experts' thought processes as they conduct the same sensemaking task. By comparing one's assessment of the situation (and reasoning behind it) at various points in time to that of one or more experts, the trainee can identify his/her development needs –how to draw meaning from particular pieces of information, how to judge relevant versus irrelevant information, how to recognize patterns of data and their implications, and how to recognize and clarify anomalies in a situation. The objective is to experiment with the FOCUS approach, using varied levels of fidelity and different techniques for providing feedback to students using the sensemaking process of the experts.

### Approach

Our technical approach is to use Situation Awareness Exercises and Cognitive Task Analysis to develop a model of sensemaking and to prepare a training application to speed the acquisition of sensemaking skill.

Situation Awareness Exercises are similar to Tactical Decision Games used by the military to train tactics and decision making. The main difference is that situation awareness scenarios have a richer description of cues in the environment. The focus is on understanding those cues and patterns of cues rather than on making a decision. The meaning of these cues will not be immediately apparent and may only make sense in the context of other cues or by mental simulation to put oneself in the shoes of the enemy. Some of the cues in the scenario will be meaningless and used as distractors.

Situation Awareness Exercises present a dilemma in an unfolding situation. At first the situation is characterized by uncertainty and ambiguity. As the situation develops, more and more information is provided, but the situation does not become clear until the participant is well into the situation. By the last situation report, everything is explained. Because of the unfolding nature of these scenarios, they can be stopped at various points to capture "snapshots" of participants' situational awareness to understand how they currently perceive and understand the situation.

Cognitive Task Analysis is the process of understanding the cognitive complexities of a task. It provides a set of tools for eliciting and representing general and specific knowledge pertaining to a particular activity, in this case, developing an accurate assessment of a situation within the Information Operations domain. The Cognitive Task Analysis allows us to go beyond procedural knowledge and behavioral aspects of tasks. The purpose is to get inside the subject-matter expert's head and understand the "cognitive map" or mental model that guides his or her ability to make sense of what is happening in a complex and ambiguous situation.

We are conducting Cognitive Task Analysis interviews with both novice and expert Information Operations officers as they "play" the Situation Awareness Exercises. We will elicit their thought processes as the situation unfolds to determine how they are interpreting and drawing inferences from cues and patterns of cues, how they are setting expectancies, what anomalies they spot and how this impacts their interpretation of the situation, and how they use

their mental models of the information operations domain and the particular context (i.e., the mission, and the cultural and political environment) in order to build and update their situation awareness. The purpose of the Cognitive Task Analysis is twofold. First, it will highlight the differences between expert and novice sensemaking skills and processes thereby providing insights as we articulate a model of the sensemaking process. Second, the data will be used in training to show less-experienced individuals the meanings and inferences that highly experienced operators draw from the pieces of information within the Situation Awareness Exercises.

### **Progress**

To date, we have developed three paper-and-pencil Situation Awareness Exercises. All three scenarios use the U.S. Army's current mission in Bosnia as the context for the fictitious events. We conducted the exercises coupled with the Cognitive Task Analysis interviews at the Land Information Warfare Agency (LIWA) at Fort Belvoir, VA. Participants included 6 expert and 6 novice Information Operations officers. We are well into the process of analyzing the data. We have identified several types of inferences participants use to make sense of the unfolding situation and found a few striking differences between novice and expert operators. The data have led us to drastically alter our model of the sensemaking process, and we are continuing to iterate the model as we glean more meaning from the data. We have also looked to other Klein Associates' data sets to understand and articulate the sensemaking process, as we seek to develop a model that is not specific to a single domain. We are also in the process of refining our training concept based on our experience at LIWA and the sensemaking model.

### **Contributions to Basic Science**

The sensemaking model being developed in this effort will describe a higher-order cognitive process that is a critical component of decision making success in naturalistic environments. Our previous research offers strong evidence that in naturalistic settings characterized by uncertainty, time pressure, and high stress, good decisions are a result of good situation awareness. In other words, once an individual knows what type of situation he or she is dealing with, the appropriate decision or course of action becomes clear. Therefore, accurate sensemaking is requisite for good decision making. This effort contributes to basic science by describing this critical cognitive process.

### **Potential Applications**

Defining the process of sense making opens the door to several applications for improving sense-making skills. Structured training programs that replicate the process of developing expertise, only more deliberately and at a faster rate, can be developed and implemented in any setting that requires making sense of a situation given mounds of data in various formats. In addition, toolsets can be generated for individuals to apply informally through the course of their work in order to refine their sense making skills and strategies.

Furthermore, by describing how humans actually use information to develop and revise interpretations of a situation, we can develop command-and-control and other technologies that work *in concert with* the human and support his/her natural process for filtering information and building and maintaining situation awareness. There may also be implications for the format in which certain types of information should be delivered, which will give an individual the best chance at interpreting the situation accurately.



## **RACO RESEARCH OBJECTIVE #2:**

*Provide fundamental knowledge to improve leader assessment and accelerate leader development.*

Research that falls under this heading provides concepts and methods for accelerating leader development, understanding and developing leader adaptability and flexibility, and discovering and testing the basic cognitive principles that underlie effective leader-team performance. Understanding the dynamics of small group leadership in face-to-face and distributed team environments is critical to this research objective as well.

# **Learning Leadership Skills in Distributed Training Scenarios: Diagnosing Strategies in Scenarios Using Latent Semantic Analysis**

**Contract #:** DASW01-00-K-0017

**Contract Dates:** 9/1/00–8/31/02

**Institution:** George Mason Univ/Univ of Pittsburgh

**PI(s):** Christian Schunn

## **Scientific Objectives**

The primary objectives of this research are to (a) test a theoretical model of expertise in complex tacit knowledge domains like leadership and (b) test a diagnosis and training approach that is based on that theoretical model of expertise.

The theoretical model being applied to leadership assumes that one important component of expertise is the effective and appropriate use of strategies. Expert strategy use generally differs from novice strategy use along four dimensions (Lemaire & Siegler, 1995). In order to provide appropriate training to a novice, one has to diagnose the particular type of strategy use problems exhibited by the given novice. The particular problems include (a) missing strategies entirely, (b) under-using generally effective strategies, (c) poorly executing strategies, and (d) executing good strategies at the wrong times.

Diagnosing strategy use in complex domains like leadership presents a difficult challenge. Thus, the secondary objectives of this research are to explore mechanisms for automatically diagnosing strategy use and larger scale problems in patterns of strategy use (along the 4 described dimensions) in complex domains, particularly the strategies found in written responses. If such a method can be developed, then this strategies training approach can be effectively applied in distributed, distance training situations.

## **Approach**

I proposed a new mechanism by which individuals can acquire training on leadership skills in distributed training situations. The first step is to construct a moderately large set of leadership scenarios to which a trainee must respond. I selected platoon leadership as the particular domain. The second step is to identify a set of common, generic strategies that could be applied to each of the scenarios. This step is implemented through a mixture of the top-down application of existing leadership literatures and the bottom-up analysis of similarities in ratings of particular possible responses by individuals across scenarios. Third, I proposed to instantiate each of those strategies for each scenario, producing strategy-scenario-ideals. Fourth, I will use a new knowledge representation mechanism embodied in Latent Semantic Analysis (Landauer & Dumais, 1997) to automatically capture strategy use in written responses to the leadership scenarios. The approach is to compare written responses for a scenario to the strategy ideals for that scenario.

The resulting set of information will be used to develop a computerized training environment for training platoon leadership skills. The computerized training environment will: (1) automatically grade the quality of written responses to the Platoon Leadership scenarios; (2) automatically categorize the strategies used in the written responses to the scenarios; (3) automatically diagnose a variety of problems in the strategy use; and (4) provide relevant training feedback to address the diagnosed problems. The components and the entire training environment will be empirically tested using ROTC Army cadets at several stages of development of the environment.

## Progress

To develop a base set of diagnostic and training examples, we have expanded the original set of 15 platoon leadership scenarios in the TKML (Tacit Knowledge Military Leadership) to 50 scenarios. These 50 scenarios cover the main types of skills typically associated with platoon leadership. The new scenarios were adapted from scenarios presented in the Army Leadership Tacit Knowledge Corpus. Because these scenarios are to be used for written responses and our goal is to diagnose particular leadership strategies in the responses, the scenarios were designed to require a single strategy response rather than a long list of different strategies.

In preparation for the LSA phase of the project, we acquired the specialized computer and software to run LSA and successfully conducted basic test runs. We then tested LSA using various military leadership databases as input, including the vignettes from the Army Leadership Tacit Knowledge Corpus and the Army Military Leadership Field Manual FM 22-100.

We collected data from 25 ROTC cadets, with each cadet generating text responses to at least 10 open-ended scenarios. We developed a set of 13 leadership strategies based on cards sorts of possible options in the Platoon TKML ratings task, and then conducted some testing of these strategies on the open-ended text data.

To develop an automatic method for coding strategies in the open-ended text responses to be used in the intelligent tutoring system, we went through a number of steps. First, a research assistant generated an example of how to implement each of the 13 strategies in each of the 10 scenarios (selecting only 10 as a trial set). These implementations were called scenario-strategy-ideals. Then LSA compared each open-ended response to these scenario-strategy-ideals and assigned the response to the strategy category with the best matching ideal. This method proved to be better than chance, but well below human coding accuracy and well below usable levels for later use in intelligent tutoring.

Through a gradual process of refinement in coding actual open-ended responses using these 13 strategies, we narrowed the set down to 10 general strategies that could be coded more reliably. We then asked a different set of 28 ROTC cadets to generate implementations of each of the strategies in each of the scenarios (5 strategies for 5 scenarios for each given cadet). Because there appeared to be multiple legitimate ways to implement a given strategy in a given scenario, we wanted data on the variety of ways this could be achieved. Coders carefully went through this forced strategy data to make sure that the cadets did indeed respond with the given strategy in the given scenario context. Only a small proportion of the forced data was removed due to not implementing the indicated strategy.

With the forced strategy data in hand, we then reconducted the LSA analyses. This time the LSA strategy coding results were close to human coding accuracy—approximately 50% agreement. Our next steps will be to use a much richer text input and improve the matching algorithm. The current text input to LSA for generating its semantic space was much smaller than is typically used in successful applications of LSA. The current classification algorithm of nearest exemplar is one very simple classification approach out of a myriad of currently existing classification algorithms. We will explore, for example, using a Bayesian approach that also takes into account secondary matches.

To study the effects of expertise on these strategies, we also collected data on the open-ended task from undergraduates completely unfamiliar with either leadership or the Army. We will be collecting comparable data from experts (lts, cpts, majors) this summer from two military bases as part of Umbrella week activities. Coding of all this data will be complete by mid-July and analyses of expertise effects should be complete by the end of August. We have already developed and tested the mathematical analyses that will be applied to measure expertise

effects along each of the 4 dimensions of strategy expertise as outlined by the model we are testing.

We have sketched out the form of an intelligent tutoring system that would use this automated classification system. We will implement and test a prototype of the system this summer. Until the classification algorithm approaches near 85% accuracy, however, there is no point in fully implementing the tutoring system.

### **Contributions to Basic Science**

The central theoretical goals of this project will be to provide a strong test of theories of expertise and knowledge representation for ill-structured domains like leadership. In particular, the data collected in this project will be used to test and refine theories of strategy selection, expertise, and knowledge representation as they apply to complex, ill-structured domains like leadership.

### **Potential Applications**

The application of our intelligent tutoring work is clear: if the automatic strategy identification methodology works and we can build a successful tutoring system. By using it, then, we will have developed a powerful methodology for intelligent tutoring in many complex, ill-defined domains.

We also expect to learn more about what common strategies can be effectively applied across a wide range of platoon leadership situations. This knowledge in itself could also be applied to other, more traditional training methods beyond the particular automated method being pursued here.

## **Interactivity, Communication, and Trust: Challenges and Opportunities for Leadership in the Electronic Age**

**Contract #:** DASW01-98-K-0009  
**Institution:** University of Arizona

**Contract Dates:** 9/15/98-3/13/01  
**PI:** Judee K. Burgoon  
**Co PI's:** Suzanne Weisband &  
Joseph Bonito

### **Scientific Objectives**

The rapid and pervasive diffusion of new communication technologies, coupled with increased emphasis on distributed teams and teamwork, is fundamentally transforming the modern military. Guided by the principle of inter-activity, two related research programs are examining the effect of these technologies on leadership, team performance, and related communication processes and outcomes. Research questions being addressed include:

1. What structural properties of communication platforms or arrangements "afford" or prevent interactivity? What communication processes are experienced as interactive?
2. How do structural properties such as mediated/nonmediated and co-located versus distributed communication affect the quality of team communication, social judgments (e.g., trust) and task performance? Which arrangements are best able to establish and maintain trust when team members do not interact face-to-face (FtF)? Which properties need to be retained or augmented to maximize leadership and mitigate effects of heavy task load?
3. Are the effects of using electronic forms of communication transitory or lasting?
4. How should leaders be trained to motivate distant team members communicating electronically to perform their best and to raise the team's collective success in accomplishing their task?

### **Approach**

#### Experimental Interactivity Research Program

In light of initial findings from pilot work and our previous research, and given the continuation contract we have been awarded, we have modified and expanded the original scope of work to include five experiments.

Experiment 1 tests the impact of user *participation*. Pairs of strangers collaborate on a decision-making task that is videotaped and subsequently viewed by observers. Observer perceptions and performance will then be compared to participant perceptions and performance.

Experiment 2 tests the effects of two additional structural properties, *mediation and geographic proximity*, by comparing FtF participants to those who engage in proximal text-based interaction and those who engage in distributed text-based interaction.

Experiment 3 tests *modality and context richness* by comparing FtF interaction to text, audio, and audiovisual interaction. In all cases, participants perform a decision-making task. After this task they complete 3 sets of measures: (1) process-related dependent measures (assessments of communication involvement, degree of coordination, mutuality, understanding, and perceived similarity among participants, and ease of interaction), (2) social judgments about their partner (a multidimensional measure of trust, credibility, and attraction toward the partner and a measure of the expectedness of the partner's behavior), and (3) outcome-related dependent measures (influence, quality of decision making, accuracy of information recall).

Experiment 4 has now become a longitudinal version of Experiment 3. It incorporates three different tasks (a social task, a case study decision-making task designed by Moberg, and the Desert Survival Problem) across two time periods.

Lastly, experiment 5 examines synchronicity by comparing processes and outcomes under conditions of synchronous (real-time) and asynchronous interaction. This research is part of a cooperative effort with a large-scale project testing strategies for achieving smoking cessation. Groups perform several tasks using Group Systems (a computerized group-support tool) under one of three conditions: (1) FtF, synchronous, (2) distributed, synchronous, or (3) distributed, asynchronous (delayed time). Group members conduct electronic brainstorming, organize concepts, ballot and prioritize strategies all via computer. This experiment permits the separation of the effects of working at a distance from the effects of interacting at the same or different times.

#### Team Development Research Program

The other prong of our research employs a field study in which four-person teams of graduate and undergraduate students in two geographically distant U.S. universities participate in virtual team projects developed for their MIS classes. The project simulates work in temporary virtual teams in that it (1) lasts 4 weeks, (2) introduces high vulnerability because the interdependent task requires team interactions to achieve objectives, and (3) entails high uncertainty as everyone is a stranger and all communications are conducted using mediated communication. To analyze strategies for interaction, we focused on the actual communication in context. Strategies associated with initiations and responses were also analyzed as way of measuring trust. To initiate interaction requires trust because it places the initiator in a position of vulnerability. The making of responses and signals inspires trust and belief that the group is responsible and skillful enough to handle the uncertainties in front of them. In addition to the electronic messages, we collected data from pre- and post-project questionnaires. These questionnaires measured demographics, school performance, computer access, team and electronic communication experience, and perceptions of leadership. Team performance was assessed by the team grade, which was mutually determined by professors in both universities.

One unanticipated addition to our field research effort was participating in the Rim of the Pacific Strong Angel 2000 humanitarian assistance/disaster relief exercise that was conducted jointly by the United Nations, the Third Fleet, representatives of all branches of the U. S. Armed Forces, and six other cooperating nations. This massive simulation of hostilities between neighboring countries included the creation of a camp for fleeing refugees. This provided an ideal "field laboratory" for examining ways in which collaborative communication and coordination could be established among representatives with diverse backgrounds and goals under highly adverse conditions in an austere environment. Results from this onsite observational project will be included in the continuation contract.

#### **Progress**

We have now collected all data for all the experiments. We have also conducted pilot tests and started to collect data for the continuation contract. We are beginning our analysis of the data for Experiment 4 (longitudinal richness) and Experiment 5 (synchronicity). We are preparing manuscripts for conference submission and publication, including an invited article for the Journal of Communication. Other work has now been published or is in press in Journal of Management Information Systems, Computers and Human Behavior, and Human Communication Research. Additionally, we have also started to analyze the field data collected as part of the RIMPAC Strong Angel 2000 exercise as part of the continuation contract.

## **Contributions to Basic Science**

### **Interactivity Research Program**

The results of this research have direct implications for current organizational theories that address distributed "virtual" processes for accomplishing work. As work becomes more global and distributed, the whole nature of organizing will inevitably be challenged and modified. Such changes need to be guided by systematic empirical work rather than by anecdote and personal experience, which in many quarters form the primary source of "data."

Moreover, the longitudinal experimental and field work closely resemble the kinds of work contexts faced by members of the same organization and members of teams assigned to projects with distant others. Therefore, the results should have greater generalizability than many prior investigations.

### **Team Development Research Program**

The results of this study provide evidence that frequent and explicit awareness communication improves team performance. In particular, it is early team interaction that contributes most to successful team outcomes. We also found that project leaders develop the interaction patterns necessary for team success. The implication is that when leaders model and promote the exchange of task information and awareness of others, the team members may be more motivated to work hard on behalf of the team.

## **Potential Applications**

### **Interactivity Research Program**

Our studies clearly indicate that for a given meeting, project, or ongoing task, the military must first determine the kinds of process and outcome goals that are required, then select or modify CISs to match task objectives with the appropriate means of communication. Our research indicates that the format selected can facilitate or undermine desired outcomes by eliciting very different kinds of communication among leaders and team members. The degree of interactivity desired must be considered in advance. Protocols should be developed that specify the "best practices" in terms of matching communication and information tools to desired objectives. Such protocols can also identify potential pitfalls to avoid or compensatory efforts that can be used so that negative consequences such as noncompliance, distrust and miscommunication do not occur.

### **Team Development Research Program**

Our field research has uncovered some features of communication that are needed to create and sustain trust so that distant teams and leaders can be successful. A natural outgrowth of this work should be the development of training procedures for leaders in mediated settings. Other potential applications are the development of software that will create a more visible form of social awareness for team members and leaders who cannot communicate face-to-face.

## **The Leadership Formula: P\*M\*D**

**Contract #:** DASW01-01-K-0004

**Institution:** The Center for Outstanding Leadership

**Contract Dates:** 09/01/01-03/01/04

**PI(s):** Reuven Gal & Micha Popper

### **Scientific Objectives**

The present study examines the leadership development process through a field study in the Israeli Defense Force (IDF). The conceptual framework suggests that leadership is a function of a given potential (P), a relevant motivation (M) and continuing development (D). These three components comprise the "formula" (P\*M\*D) for outstanding leadership. All three components are necessary prerequisites for actual effective leadership.

This "formula" and the theoretical framework behind it extend the leadership literature by emphasizing internal aspects (e.g., personality predispositions, motivational needs and developmental processes) that give rise to the potential to become and the motivation to assume leadership positions. Our argument is that only those who have sufficient "ego resources" (self efficacy, internal locus of control, low level of anxiety, secure attachment pattern and tendency for optimism), are highly motivated to lead, and are "open" to personal development can become leaders.

Guided by this conceptual framework, our research hypotheses are as follows:

1. 'Leaders' will report higher level of self efficacy compared to 'non-leaders.'
2. 'Leaders' will exhibit a stronger internal locus-of-control than 'non-leaders.'
3. 'Leaders' will demonstrate higher level of optimism than 'non-leaders.'
4. 'Leaders' will be characterized by lower level of trait-anxiety than 'non-leaders.'
5. 'Leaders' will be characterized by a 'secure' or 'avoidance' attachment pattern, whereas 'non-leaders' will be characterized by an 'anxious' attachment pattern.
6. 'Leaders' will have a higher level of motivation to lead than 'non-leaders.'
7. 'Leaders' will report a greater number of and more powerful 'leadership-shaping' experiences accrued in their early childhood and adolescence periods than 'non-leaders'.

### **Approach & Progress**

This study is based on a comparative study of several samples of IDF soldiers (from Infantry and Armour) undergoing basic training. By distinguishing "leaders" from "non-leaders" and subsequently assessing various P, M and D measurements, this field study will enable the examination of our three categories of hypotheses related to the leadership formula: potential, motivation and development.

In order to test our research tools (especially the new tools we have constructed) and to test the research procedures (working with army units), we conducted a pilot study. This pilot study was conducted during the months of February and March 2002. Participants included 195 soldiers from Infantry and Armor units. We have started to analyze this data. Additionally, we returned to the same soldiers a few weeks back (May 2002) in order to test the reliability of the new questionnaires we developed.

So far, the findings concerning the potential and motivational variables seem to support our hypotheses. Currently, we are examining the developmental variables by analyzing the data obtained from LSE interviews and questionnaires.



### **Contributions to Basic Science**

The results obtained from the pilot study support our 'potential' and 'motivational' hypotheses. To become a leader, one should have (a) enough "ego resources" (self-efficacy, internal locus of control, low level of anxiety, secure attachment pattern and tendency for optimism), and b) a strong motivation to lead others. An examination of the developmental issues is currently underway. After completing this final analysis, we will test our leadership formula using the pilot data.

It is important to understand that the actual field study (that will start in September 2002) will further examine our hypotheses, especially the ones that focus on development. Our main scientific contribution thus far (up to this research stage) has been in forming and constructing new leadership tools. We have expanded the "motivation-to-lead" concept, both substantially and technically. We have prepared three developmental leadership tools: 1) an openness to experience questionnaire, 2) the LSE interview and 3) an LSE questionnaire. Finally, we have formed a questionnaire to identify leaders and non-leaders.

### **Potential Applications**

This research is being conducted in the Israeli Defense Force (IDF). Unlike civilian organizations, in which leadership is diffused in the manager's functions and formal authority, in the military 'net leadership' is much more prominent. In fact, leadership is the essential driving force that affects a soldier's readiness to risk his/her life. Furthermore, within the military, the distinction between 'leaders' and 'non-leaders' is much more apparent than in most other institutions. However, this distinction is somewhat contaminated in those military organizations (e.g., U.S Army) in which the differentiation between officers and non-officers is done 'institutionally' (i.e. through military academies) rather than 'naturally' (namely, through a selection process).

A unique example of the latter type occurs in the IDF. Starting on equal footing, all Israeli conscripts are gradually undergoing an ongoing selection process during their initial training period. This unique situation makes the IDF an extraordinary natural laboratory to examine leadership development. Moreover, this field study is being conducted on two different army units (Infantry and Armor) in order to examine whether they undergo different leadership-forming processes.

Overall, this study provides a unique opportunity to understand how 'leaders' differ from 'non-leaders,' what makes 'net-leadership,' and how it develops. Furthermore, our research may unravel some of the mysteries related to the nature-nurture origins of leadership as well as suggest some important practical implications related to leader selection and development in any modern military.

## **Developing Effective Military Leaders: Facilitating the Acquisition of Experience-Based, Tacit Knowledge**

**Contract #:** DASW01-00-K-0014  
**Institution:** Yale University

**Contract Dates:** 9/01/00 – 9/30/03  
**PI(s):** Robert J. Sternberg

### **Scientific Objectives**

The purpose of our recent research efforts is twofold. First, we seek to deepen our understanding of the cognitive processes occurring during the acquisition and application of tacit knowledge (TK) to solving practical problems. Second, we seek to establish that training interventions can enhance practical problem-solving skills and the ability to acquire TK from experience. This work represents an extension of previous research indicating a relation between TK and occupational performance in that (a) we have begun to characterize the underlying processes through which TK aids in problem solving, and (b) we are using our knowledge of these processes to understand how they may be facilitated through training.

### **Approach**

Our approach to illuminating the cognitive processes underlying the acquisition and application of TK to practical-problem solving involves the development of extended case studies that reflect the use of metacognitive problem-solving processes. In contrast to measuring the outcome of having TK through quality ratings of problem-solving strategies, the extended case studies allow measurement of cognitive processes involved in applying TK through the use of open-ended questions that deal with (a) problem identification, (b) solution generation, and (c) outcome monitoring. We have examined (a) the measurement properties of these three cognitive-processing factors, which appear to be sound, and (b) the relationship between officers' scores on these factors and their scores on the Tacit Knowledge Inventory for Military Leaders (TKML), in which some interesting patterns have been found.

Our approach to enhancing TK acquisition involves designing competing interventions to facilitate the acquisition of TK, each of which emphasizes a different aspect of TK. One intervention will emphasize the condition aspect of TK, drawing attention to the conditions that are identified as triggers for action. Another intervention will emphasize the action aspect of TK, providing methods for reflecting on action outcomes. A third intervention will target both the condition and action aspects of TK. Each intervention is designed to provide leaders with the skills needed to regulate their own learning. We will compare the outcomes of each intervention to each other, as well as to a non-intervention control condition. We will test the effectiveness of each intervention on learning and performance outcomes at varying levels of command.

### **Progress**

To date, our research regarding the cognitive processes underlying the application of TK to practical problem solving have produced promising results. Specifically, using confirmatory factor analysis we have made the following key discoveries: (a) our measures of cognitive processes (i.e., the case studies) are reliable and stable, (b) performance on these measures could be best accounted for by three metacognitive problem-solving factors comprising problem identification, solution generation, and outcome monitoring, and (c) the relation between problem identification and TK scores was strongest of all the problem-solving factors, independent of rank. These findings are currently being prepared for publication.

In the past year, we have restructured the design of our TK training interventions relative to our initial proposal, based on a completed literature review and our latest findings. In addition, because of changes in access to active-duty military leaders (as a result of the terrorist attacks on September 11th), we have worked to gain inroads to other military personnel to participate in our research. We will be working closely with Army personnel and reviewing Army documentation to structure our instructional materials for maximum face validity and benefit to military participants. In particular, we will be working with LTC Jim Rice, MAJ Benjamin Webb, and the soldiers of 1st Battalion, 1st Infantry at the U.S. Military Academy. We have drafted (1) preliminary versions of our instructional materials, which include an outline of the instructional goals and learning outcomes of the intervention, (2) a set of discussion questions based on the case study that will be administered as part of the TK pre-tests, and (3) response data from expert leaders indicating the "correct" answers to questions on the case study and (4) predictions for the outcome of particular alternative problem solutions.

### **Contributions to Basic Science**

A theory that attempts to explain human functioning in everyday life is by necessity complex and multifaceted. Testing and improving this theory is a long process, in which the theory is addressed piece by piece. The major contribution of the current work to basic science is the illumination of a previously unexplored piece of the triarchic theory of intelligence. This piece describes the knowledge-acquisition components, the metacognitive problem-solving components, and the performance components of practical intelligence and the role each plays in TK acquisition and application. Specifically, the current research has demonstrated that the metacognitive processes hypothesized to be involved in practical problem solving do exist and can be measured. Furthermore, this research has demonstrated that particular metacognitive processes play a differential role in TK and practical problem solving. These results support the findings of previous research investigating expert/novice differences in performance which have indicated that experts spend more time on problem diagnosis than any other aspect of problem solving. These results further add to the expert/novice research by providing stable and reliable measures of metacognitive problem-solving skills and by indicating a relation between problem representation and the acquisition of knowledge that is used in problem solving. The current research will explore the symbiotic relationship between knowledge-acquisition components and metacognitive processes.

### **Potential Applications**

Our latest research findings have specific implications for the development of leadership capability. Current explicit leadership instruction does not provide a way in which leaders can translate leadership principles into actually solving practical leadership problems. Because the complex and ever-changing nature of job environments precludes teaching leaders what must be done in every problem situation, leadership instruction must instead provide leaders with the skills to use experience as their career-long mentor and source of feedback. By demonstrating that measures of the cognitive processes used in TK and practical problem solving are stable and reliable, we have made inroads to developing instructional materials that can provide useful feedback to cadets or leaders participating in leadership training programs. Further, by identifying the cognitive processes most critical to predicting TK scores (i.e., those involved in problem identification), we have provided a critical target for focus in leadership training.

## **Workshop on Leadership at a Distance**

**Contract #:** DASW01-00-K-0001

**Institution:** University of Arizona,  
Arizona State University

**Contract Dates:** 12/18/00 -3/31/03

**PI:** Suzanne Weisband

**Co PI:** Leanne Atwater

### **Scientific Objectives**

Previous social science research on issues related to leadership has discussed the importance of leading people remotely and the difficulties inherent in doing so. However, the empirical research on leadership in geographically dispersed work is not well integrated nor well understood. The rapid and pervasive diffusion of new communication technologies, coupled with increased emphasis on distributed work units, is fundamentally transforming the modern work force, including the military. With these changes have come new challenges and opportunities for the exercise of leadership. Among the challenges are:

- An increased amount of "remote work," in which the nature of work is at a distance;
- Training with leaders at one location and followers at another;
- Complex work arrangements where leaders and followers are in multiple geographic locations at different times;
- People are members of multiple teams and report to multiple leaders.

### **Approach**

Workshop organizers invited 25 top scholars for a 3-day event in October 2001 to present draft chapters related to leadership at a distance. Our goal was to draw from multiple disciplines, mainly in the social sciences and leadership fields. Each author was responsible for presenting their work, as well as for reviewing and presenting one other chapter. Each presentation (of the paper and the review) was then followed by a 10-15 minute period of questions. A few authors chose not to attend at the last minute due to the events surrounding 9/11 and apprehension about flying. These authors were given the opportunity to present their work via audio conference, while local participants viewed the PowerPoint slides.

### **Progress and Application**

Two deliverables of this workshop are: (1) a website where research ideas and papers to be published in the book will be shared by participants (abstracts of which will be advertised to the public), and (2) the publication of an edited book. The website is available at <http://www.distant-leaders.org>. A book proposal has been submitted to Lawrence Erlbaum and Associates (LEA). We are awaiting 3 chapter drafts, all of which are expected by June 15, 2002.

## **Distant Leadership Under Stress**

**Contract #:** DASW01-99-K-0003

**Contract Dates:** 08/01/1999-07/31/2002

**Institution:** University of Maryland, Baltimore

**PI's:** Yan Xiao, Colin Mackenzie, and  
Katherine Klein

### **Scientific Objectives**

The overall objective of this project is to investigate leadership effectiveness when leaders are distanced from the team. Since the role of leadership in team performance is important, understanding how leadership impacts team performance is important to military as well as to civilian organizations. With the widespread use of electronic communication technologies, it has become essential to establish a theoretical and empirical basis for predicting how new communication technologies may impact leadership and team performance.

To achieve a better understanding of distant leadership under stress, this research program involves two intertwined efforts. The first is to develop a conceptual model of the interaction between task structure, stress, communication modality, and leadership effectiveness. The second is to conduct an empirical study of distant leadership using a real, dynamic, and stressful work environment as a laboratory. The specific goals of this research are as follows: (a) to develop a matrix of leadership functions and situations in which specific functions are needed; (b) to develop a leadership model which prescribes the nominal processes through which a leader controls and influences team activities, either co-located or at a distance; (c) to develop leadership measures applicable to leadership in a dynamic, team environment; and (d) to conduct a series of prospective studies in a real, event-driven, stressful environment to evaluate the impact of various communication modalities on leadership using the measures developed.

### **Approach**

The theoretic and conceptual efforts (aims a-c) will be based on existing literature on team performance and on the analysis of an existing video library of team performance collected in a stressful environment. The cases from the video library will be reviewed to extract segments representative of effective and ineffective occurrences of leadership. These segments will be used as the basis for the leadership matrix, model, and measures. Prospective empirical efforts (aim d) will utilize an already established study environment in a Level-I trauma center. Comprehensive audio-video recordings will be the primary data collection method. Two modes of communication will be randomly assigned in consecutive cases. Leadership effectiveness will be measured by both team performance (speed and accuracy) and process parameters (decision processes and leadership control processes). These dependent measures will be analyzed in relationship with several independent variables including risk, urgency, uncertainty, task structure, and workload.

### **Progress**

#### Dimensions of Leadership Behavior

Up to this point, we have selectively reviewed existing literature on leadership functions in team settings. One fruitful focus area has been contrasting the team structures in trauma centers with those structures used in many other settings. Through our review efforts, it has become clear that teams in trauma centers have characteristics that are of interest to the Army. The review efforts also suggest significant gaps in the theoretical framing of leadership functions. Two manuscripts are underway (one presented at Society of Industrial and

Organizational Psychology annual meeting) to describe the theoretical progress. In particular, the concept of shared leadership, in which different members in a team enact leadership at different times, has been proposed.

We have conducted 10 interviews and 70 hours of direct observation in the trauma center to refine and elaborate our conceptual model guiding our study of distant leadership. In addition, we gathered survey data from 30 members of the trauma centers. Six leadership behavior dimensions were identified as frequently occurring and critical to team success. This finding was incorporated into the measurement plan of experimental work.

#### Experimentation on distance leadership

During the last reporting period, we have successfully executed the most challenging phase of the project: experimentation on leader location in real-life trauma patient resuscitation.

Overview. In order to assess the potential impact of distant leadership, we outfitted a level-I trauma center's patient admitting area, where trauma patients are brought in for initial stabilization, resuscitation, and diagnosis. In the distant leadership condition, the leader of a trauma team (the attending trauma surgeon) was told to be at a distant location where he or she could supervise the patient resuscitation through video, audio, and data link. To allow comparison, co-locational and distant leadership conditions were randomized whenever logistics permitted. Dependent measures included: (1) surveys for each session completed by some of the team members before and after the initial resuscitation, (2) a debriefing after each session, (3) physiological measures of stress (saliva amylase), (4) audio-video recordings (analysis methodology outlined below), and (5) patient status.

Data collection effort overview. Surveys, interviews, video and other data were collected from cases that arrived in the TRU between 10 am and 5 pm, Monday through Friday for two blocks of dates: between March 5 and April 6 and between May 7 and May 30. Additionally, during the designated hours in May, observational data on non-videotaped cases were collected in which data on team membership and patient conditions were collected for cases.

There were 59 taped cases collected on 37 separate days. Of the 59 cases, 32 of them involved local leadership condition, 22 involved remote (distance) leadership, and 5 were anomalous, involving a mix of distance and remote. An additional 68 cases were observed, but not taped on 19 days (some overlapping with "taped" days). Thus, there were a total of 127 cases either taped or non-taped.

Of the 89 participants involved in videotaping, 26 were staff (8 surgical attendants, 5 anesthesia attendants, 13 nurses and technicians), and 63 were in training (6 surgical fellows and chief residents, 51 residents, and 6 medical students).

Data analysis. All post-session debriefings have been transcribed. Initial analysis of the transcripts was the basis for two manuscript submissions. The first was for a workshop on distant leadership organized by Leanne Atwater and Suzie Weizband. The second was for the annual meeting of Human Factors & Ergonomics Society. A central theme in the debriefing materials is that the teams adapted their structures in response to two factors: (1) the management of dual goals of the team: training and performance, and (2) the combination of task conditions and team experience.

Video analysis. A significant portion of the video analysis has been accomplished. This included a review of videotaped sessions by subject matter experts (who were not part

participants in the research). During the review, each subject matter expert filled out a questionnaire that provided his/her opinions on the leadership and team performance observed. In addition, a measure of time and accuracy was captured on a set of pre-defined landmarks during patient resuscitation.

#### Further analyses

A number of data analysis activities will be completed during the remainder of the project. First, we plan to carry out multivariate analyses. Initial analyses have shown great promise of some very important research findings. Second, we plan to further analyze the videotapes to extract segments highlighting leadership situations and to see how leadership behaviors changed accordingly in response to task situations, team experience, and leader location. Third, we plan to further code verbal and non-verbal communications.

#### **Contributions to Basic Science**

Our research has several unique features as compared to previous leadership research. First, we focus on the performance-based measurement of leadership effectiveness in a highly dynamic team environment. Second, our empirical data is from a real environment. Third, our study environment allows direct observations and audio-video recordings of real team activities under stressful situations and the manipulation of communication modalities between leaders and team members. Fourth, the task situation characteristics (high-risk, high-tempo) provide a basis for studying highly reliable, rapidly assembled and flexible teams.

In our initial analyses, we examined changes in team structures due to the impact of distant leadership, team experience, and task urgency. We proposed a set of team structure archetypes as a way to reflect the impact of team experience, leader location, and task urgency. Previous studies on leadership and team performance have not examined team structure in this manner. Instead, research has typically assumed only two team structures: 1) undifferentiated (such as self-managed teams), or 2) a leader-follower/s dichotomy.

Additionally, our analyses thus far, based on debriefing materials and verbal communication, have demonstrated that leaders and teams adapt their structure both across sessions and within sessions. We attribute our findings to two potential causes: (1) team members were differentiated in terms of experience and authority, and (2) teams were in a real environment. We believe that measuring team structures is an effective way to capture distant leadership and that the findings associated with team structure will have direct implications for training and team-technology design.

#### **Potential Applications**

We anticipate our efforts will fill a void in the literature. In particular, our research will help us to understand leadership processes in the context of team performance and provide a basis for future training programs and other interventions to enhance team performance, especially when leaders and members are separated by distance.

Although data analysis is still underway, we will highlight one potential impact of our research on team-technology design. Due to rapid changes found in some work settings, teams may encounter dynamic task conditions in which they have the dual goal of successful training and performance. Our experimental results suggest that team leaders adapt how they communicate with their team members. This ability to control and rapidly adapt configurations of communication channels (who talks to whom and who can hear what) is critical. The leaders in our research showed preference for a hierarchical communication structure, but would alter that structure when task urgency was high or the team was inexperienced working together.

# **Leadership, Team Processes, and Team Adaptation: The Development and Influence of Functional Leadership Capabilities on Team Adaptability to Adversity**

**Contract #:** DASW01-98-K-0005  
**Institution:** George Mason University

**Contract Dates:** 8/1/98-7/31/03  
**PI:** Stephen J. Zaccaro  
**Co-PI:** Richard Klimoski

## **Scientific Objectives**

Leadership and team performance are critical elements of military effectiveness. Yet, despite vast literatures on leadership and team dynamics, respectively, there is surprisingly little conceptual research on precisely how leaders create and direct team processes to achieve collective success. In particular, there has been little consideration in both the teams and leadership literature given to (a) the team cognitive, motivational, and coordination processes that specifically promote team adaptation; (b) how leaders influence the quality of these processes; (c) the personal qualities of the leader and of team members that promote team adaptation; and (d) leader and team training principles that specifically foster team adaptation.

The purposes of the proposed research program are (a) to examine in more detail the influences leaders have on team processes contributing to team adaptation, (b) to examine training and development principles that contribute to the development of adaptive military leaders and teams; and (c) to develop and examine the psychometric properties of a leader assessment tool that measures personal qualities contributing to adaptation. We are meeting these objectives with a series of experimental and field studies in which we examine leadership and the motivational, cognitive, and coordination processes that contribute to team adaptation. We also intend to examine and validate integrated leader and team training and development guidelines that would foster these processes. Finally, our research efforts will also yield assessment tools designed to measure the influence of leader characteristics on leadership and team adaptability.

## **Approach**

This research effort is composed of both experimental and field studies. The experimental studies are intended to examine (a) leader attributes that promote leader and team adaptation, and (b) training feedback characteristics that foster team adaptation. The field studies are designed to (a) validate an assessment battery constructed to measure multiple attributes related to leader flexibility, (b) examine work experiences related to the development and emergence of attributes promoting leader flexibility, and (c) test training principles regarding the development of leader flexibility. We have used the Army War College as a site for these field studies. In a related effort we have cooperated with Industrial College of the Armed Forces to offer a course in leader adaptability.

## **Progress**

We have completed four experimental studies. Our first study examined the effects of process versus outcome feedback, and individual versus team-level feedback on team adaptation. We also examined the role of certain leader adaptability attributes on team processes and performance. In our second study, we investigated other dimensions of training feedback, including public versus private feedback, on team efficacy and team mental models, as well as team adaptation. In our third study, which we recently completed, we examined the role of



variability in training performance scenarios on adaptability. We are currently analyzing the data from this study. In our fourth study, that is still ongoing, we are exploring in more detail the nature of team mental models.

For the field research, we have developed conceptual models that describe the influences of work experiences, formal instruction, mentoring and coaching processes, feedback systems, and self-development experiences on individual attributes related to leader flexibility. We have also developed an assessment battery that measures cognitive, behavioral, and dispositional attributes linked to leader flexibility. We have completed several validation studies, affirming the psychometric strengths of this battery. We also examined the influence of these attributes on the relationship between reported developmental work experiences and gains in tacit knowledge in military officers. We have administered this battery to several classes at AWC and to a sample of managers and executives in several private corporations. We are continuing our examination of archival sources of work experience data in order to relate specific categories of work experiences to the development of key leader adaptability attributes. Finally, in cooperation with the Center for Creative Leadership, we are developing criterion measures to assess the relationship between leader adaptability traits and reactions to organizational change in one of their leader performance simulations. This study will allow us to validate the proposed leader attributes as predictors of processes and performance.

In related efforts, we have developed and pilot-tested a proposed training curriculum at the Army War College. This program applies principles of adaptability training that were derived from the conceptual models developed in year one of this effort. We have implemented full versions of this course at AWC in Spring, 2001 and at ICAF in Fall, 2002. These applications of our research did not allow for a training evaluation. We are currently exploring other venues for such evaluations. We are also revising components of this training for use in a adaptive leader training program being developed by PDRI. We will explore this as a possible venue for training evaluation.

### **Contributions to Basic Science**

One product of this effort is a comprehensive conceptual framework that describes a career-long process of leader development. This framework builds on previous research in the literature and incorporates multiple sources of developmental experiences (i.e., formal training, self-development, work assignments, mentoring, coaching, feedback). Accordingly, it is particularly appropriate for the U.S. Army. Also, the data from the planned laboratory and field studies should validate training principles regarding the efficacy of particular kinds of interventions designed to grow adaptability skills. These data should also provide information regarding the development and influences of leader and team attributes that promote adaptability. Finally, we have a growing database that provides validity for proposed relationships between certain key leader attributes and adaptability.

### **Potential Applications**

The applications of this research for the Army are expected to be in the areas of training assessment and curriculum. If validated, the assessment battery measuring leader flexibility can serve as a very effective training tool in multiple Army training settings. Further, the field studies are expected to yield specific guidelines and curriculum tools that target the development of leader flexibility. These guidelines and tools are expected to be constructed in accordance with the different developmental needs that emerge at various points in an officer's career. Also, the adaptability-training program being implemented at AWC should have direct applicability to the development of adaptive senior leaders.

### **RACO RESEARCH OBJECTIVE #3:**

*Provide fundamental knowledge for identifying and measuring the attributes and skills that are critical to soldier recruiting, performance, and retention in the transforming Army.*

Research in this section is directed toward identifying and measuring the aptitudes and skills that are unique to the human performance requirements of the Objective Force. Exploring the sociological and psychological factors that could influence recruitment, retention, and Army performance are important aspects of this research objective.

## **International Military Education and Training: A Sociological Analyses**

**Contract #:** DASW01-98-K-0003  
**Institution:** Northwestern University

**Contract Dates:** 6/1/1998-12/31/2001  
**PI:** Charles Moskos

### **Scientific Objectives**

The research bridges methodological and theoretical issues found both in social science dealing with military organization and those dealing more generally with cross-cultural cooperation in international organizations. The research advances social science understanding of intercultural and interpersonal relations within large-scale organizations. One specific goal is to identify factors that help or hinder effectiveness within multinational military organizations. As with prior ARI-sponsored projects, the research agenda is also subject to direction from senior officials in the military and U.S. government. The research goals are explicitly dynamic in order to incorporate developments during the period of the research.

### **Approach**

Since 1950, some 500,000 international military officers and senior enlisted personnel have received professional military education through the International Education and Training (IMET) program of the United States. In the Post-Cold War era, IMET plays an even more important role with regard to multinational operations that encompass nontraditional missions (e.g. peacekeeping, humanitarian, and nation building) as well as conventional military concerns. This research has attained new significance since the events of 11 September 2001 and the ensuing war against terrorism.

The approach is threefold: (1) research on IMET participants in the United States, (2) research on IMET graduates in their home countries, and (3) research on comparable programs in other advanced Western democracies. The methodology is primarily in-depth interviews with students, graduates, and staff members of professional military education (PME) programs.

### **Progress**

The first phase of the IMET study is completed and was submitted as a Technical Report to ARI in September 2001. Interviews were conducted in the war and staff colleges in each of the services: Army, Navy, Air Force, and Marine Corps.

The second phase of the IMET research is also completed and involved: (a) interviewing IMET alumni in their home countries (10 interviews) and (b) comparisons of the American IMET program with equivalent PME programs in the United Kingdom and Netherlands. Additionally, the PI was personally invited by the SACEUR to conduct interviews (April 2001) at NATO headquarters on issues of multinational cooperation. The cooperation extended the PI by the host institutions was extraordinary. In addition to presentations to senior military officers, briefings were requested by senior officials of the National Defense University and the Army War College, as well as the U.S. State Department.

### **Contributions to Basic Science**

The data along with the concepts introduced in this research will inform social scientists doing basic research in several areas. One is the role of multicultural communication with formal organizations. A second is to document the relative weight of cultural, organizational, and economic variables in fostering or reducing levels of cooperation among employees in

civilian organizations as well as among officers in military organizations. Perhaps, most significantly, it will help identify distinctions between personality factors and sociological variables in multinational organizations.

### **Potential Applications**

Overall, IMET is a most cost-effective way of enhancing international military cooperation. One notable finding was that many military officers often feel closer other officers of different nationalities in multinational organizations than to fellow-national civilians in the same organization. Certain problem areas were analyzed with attendant recommendations for improvement. These include: (1) make medical insurance available to the family members of all foreign officers; (2) decrease the class material unavailable to international officers because of security classification; (3) add more curriculum content on multinational operations; (4) encourage more cross-national activities, e.g. informal dinners, excursions; (5) encourage American officers to become more familiar with the home country of international officers with whom they regularly work; and (6) extend more effort to incorporate the spouses of international officers into the American social scene.

## **Social Structures Affecting Army Performance**

**Contract #:** DASW 0100 K 0016  
**Institution:** University of Maryland at  
College Park

**Contract Dates:** 8/17/2000- 8/16/2004  
**PIs:** David R. Segal and Mady Wechsler  
Segal

### **Scientific Objectives**

This program of research is focused on the identification and analysis of changes in the international environment, American society, the U.S. Army, and the American soldier that are consequential for the fulfillment of Army missions. The research program is organized into four related areas: (a) research on American populations, (b) research on soldiers and their families, (c) diversity in the military, and (d) comparative military institutions.

### **Approach**

The research approaches, both qualitative and quantitative, vary among our four program areas, as follows:

#### Research on American Populations

Most of our research in this area has focused on the youth population from which the Army's recruits are drawn. In particular, collaborating with colleagues at the University of Michigan, we utilize the Monitoring the Future (MtF) database. This program of research surveys about 16,000 high school seniors each spring semester and has been doing so since 1975 (the second year of the current volunteer force). Sub-samples of seniors are then surveyed semi-annually for several years after high school graduation. Among the areas covered in these surveys are military-related attitudes and behaviors.

#### Research on Soldiers and their Families

In this area, we conduct surveys of soldiers in selected units and surveys of military wives. We also conduct interviews with soldiers and spouses, conduct observations of units in the field, and draw upon documentary materials in a variety of archives.

#### Diversity in the Military

Our concern here is how individuals adapt to the military and its missions and how this adaptation is affected by race, ethnicity, gender, and sexual orientation. We draw upon our own surveys and observations, secondary analysis of other surveys, and field observations.

#### Comparative Military Institutions

Our goal here is to draw upon the experiences of foreign military forces to identify cross-national similarities and differences as well as to learn from the experiences of others. Our approaches have been (1) to encourage cross-national groups of behavioral scientists to engage in parallel research efforts in their own countries and to pool the knowledge acquired and (2) to conduct surveys within the armed forces of other nations.

## **Progress**

Seven research reports have been published during this first contract year including four journal articles and three book chapters. Copies of these have been provided to ARI. An additional five publications have been submitted for publication review. Seven additional papers were presented at professional conferences. In the following section, we provide an overview of the research findings we have published.

### **Research on American Populations**

Regarding American youth, the major research published this year dealt with (1) sex differences in high school seniors' propensity to enlist in the military, (2) differences between military preferences and expectations, (3) sex differences in the relationship between propensity and actual service, (4) effects of background and educational characteristics on propensity and enlistment, and (5) the post-high school activities of men and women who do not serve. Using data from the MtF surveys, we found that young women's propensity to serve is lower than men's, but that more women desire than expect to serve. The relationship between propensity and service is weaker for women than men, and these relationships have not increased over time. Background characteristics, educational achievement, and educational plans are less predictive of women's propensity and enlistment than men's, with the exception of greater race and ethnicity effects among women. Having children has a small negative effect for low propensity men's enlistment. Lastly, more women desire and expect to serve than the military is enlisting.

### **Research on Soldiers and Their Families**

Our research on military personnel has addressed issues of downsizing and deployment tempo. In one of our survey research efforts, we analyzed the impact of multiple deployments on peacekeeping attitudes, personal morale, and reenlistment intentions of American soldiers. In terms of peacekeeping attitudes, the greatest effects were on judgments of the appropriateness of alternative personnel to perform peacekeeping operations. With respect to morale and reenlistment intentions, we found support for the negative impact of multiple deployments on personal morale. However, we found no statistical support for the relationship between number of deployments and reenlistment intentions.

A more socio-historical view of military service in the United States sought to clarify the origins of citizen service in the United States. It departed from the premise that military service compelled by the state and performed as an obligation of citizenship may be understood as constitutive of citizen service. Based on this analytic distinction, the article developed one central argument. Citizen service was first realized in the United States during the American Revolution, but not as might be expected in the compulsory militia dating from the colonial period. Rather, citizen service was realized first in the form of the federally mandated conscription of American national citizens into the Continental Army, a peculiarly Revolutionary contribution to the War of Independence. Citizen service's Revolutionary birth in national conscription, then, helps to recast the very roots of the American military tradition.

### **Research on Diversity in the Military**

Our research on gender and propensity to serve in the military (also discussed above as part of our research program on American youth) falls into the diversity area as well. One report based on this research discusses ways in which the military creates, sustains, and reflects gender and sexuality norms, stereotypes, and stratification. In particular, the relationships between the military, gender, and sexuality can be examined at multiple levels. At the societal level, the paper discusses ways in which the military affects the social constructions of gender and

sexuality, as well as how society's gender structure affects women's military participation. At the organizational level, it describes the current legal and demographic status of women and homosexuals in the U.S. military. At the individual/interpersonal level, it describes how gender and sexuality are constructed and reconstructed through the daily interactions of military members. Included are summaries of the participation of women and homosexuals in the armed forces and the policy conditions of their service.

#### Research on Comparative Military Institutions

In regards to our research program on comparative military institutions, part of our research focused on the Russian Army. The Russian Army, like many modern military forces, underwent a major downsizing during the mid-1990s. This project intersects with our research on soldiers and their families. We conducted an analysis of quality of life and mental health survey data of Russian army officers and their wives in four conditions: (1) those who survived downsizing; (2) those still in the army but expecting to leave; (3) those who left and found civilian employment; and (4) those who left and had not yet found civilian jobs.

The groups reporting the highest quality of life were not the survivors of downsizing, as has been found in most downsizing research, but rather those who had left the army and found civilian jobs. The same pattern held for the officers' wives. With regard to mental health, the group reflecting the highest levels of depression, anxiety, and hostility were those soldiers who were still in the army but were expecting to leave, while the group reporting the least distress were employed veterans. Again, the same pattern held for the officers' wives. Thus, leaving the Russian Army through downsizing produced no more distress than surviving downsizing. This fact may make Russia's proposed transition from a conscription-based army to a professional force difficult to achieve.

A more comparative research effort in this area presents a historical overview of the field of military sociology as a context for discussing the kinds of structural changes that have taken place in military organization since World War II. It describes the emergence of a "late Cold War" military structure after the Vietnam War and of a "Post-Cold War" military after the collapse of the Soviet Union. Characteristics of this post-Cold War structure are discussed. Reductions in defense expenditures and in military force size in the nations of Western Europe and Latin American are presented.

Another comparative effort dealt with the conceptualization of change in military organizations. Social scientists concerned with the processes of change within military organizations have begun to appropriate the language of postmodernism in order to describe a number of transformations observed in military forces cross-nationally since the end of the Cold War. Although the thesis of the "postmodern military" may have a novel appeal to scholars across a broad range of disciplines, we argue that while substantial changes are indeed occurring in the armed forces of Western countries, there is at present little evidence to suggest that these changes are postmodern in nature. On the contrary, most of the developments in contemporary armed forces being described as such are actually modern in character—emerging as the result of rational, purposeful adaptation to environmental contingencies. We argue that the intellectual discourse of postmodernism is useful for military sociology only to the extent that scholars are able to apply discrete strands of postmodern social theory to predict or explain processes of change. We examine the utility of three such stands: post-industrialism, post-Fordism, and globalization. Finally, alternate criteria, heretofore marginalized in the discussion of the postmodern military, are suggested as benchmarks to determine the degree to which the armed forces have indeed become postmodern.

### **Contributions to Basic Science**

Much of our work feeds directly into ongoing paradigm shifts in the behavioral and social sciences. The nature of the human life course has been a major paradigm. In particular, our work on the antecedents of military service has helped shape how decisions made by young people about their post-high school trajectories are treated from this theoretical perspective. Similarly, our work on the post service experiences of those who have worn the uniform extends our understanding of the other extreme of life course trajectories. Complementing this, our work on military families has fed directly into a paradigm shift in the study of labor market dynamics that increasingly focuses on social structural determinants rather than characteristics of individuals.

Methodological advances have accompanied these conceptual contributions. Specifically, we have expanded the utilization of hierarchical linear modeling as a tool to measure the effects of social structures (such as military bases or military units). This allows us to obtain more reliable estimates of these effects than can be derived from the more traditional Ordinary Least Squares models or their single-level variants.

Postmodern models postulate revolutionary breaks from the past and reject much of the canon that has been accepted in theorizing about the military. Our work on organizational change has been extremely influential in shaping the debate among behavioral scientists who analyze the military on the degree to which these postmodern models can be usefully adopted as a strategy for "out of the box" thinking.

### **Potential Applications**

Our research has a number of obvious potential applications. First, the research on American youth attitudes toward military service and the military as an organization has implications for recruitment strategies. Second, our labor market dynamics research highlights a problem area that policy-makers concerned with the quality of military life, as a factor in the retention of military personnel, must attend to. Third, our research on the attitudes and behavior of military personnel can help inform Army doctrine on the kinds of soldiers that should be used in stability operations and special training they may require. Finally, our cross-national research allows us to identify human resource management strategies that have been implemented in other nations that might be useful in the U.S.



## **Strategic Recruitment and Retention: Preference Structure, Expectations, and Choice**

**Contract #:** DASW01-00-K-0011  
**Institution:** California State University,  
Hayward

**Contract Date:** 8/1/00 to 7/31/02  
**PI:** Mary Kay Stevenson

### **Scientific Objectives**

The purpose of this research program is to develop a general model of how individuals evaluate job opportunities that involve both current and future benefits when choosing to accept a position and stay in a position. The studies that are described in this proposal use temporal discounting theory and theories of decision making to assess the relevance of laboratory findings to career decisions. Research in temporal discounting has indicated that future incentives can have less impact than current outcomes in some contexts. However, the data for this research has been primarily generated by asking subjects about fictitious or relatively limited outcomes. The approaches are characteristic of studies that analyze groups of subjects. Image theory has proposed a mechanism for structuring the screening of decision options and monitoring the relationship of an individual's expectations with their experience. The current theory uses Policy Modeling to create an analysis of those expectations that focus on individual differences. Recruitment and retention strategies will be developed based on the derived preference structures and decision theory. By modeling the impact of uncertainty on the recruits' expectations and the stability of the preference structures over time, we can predict when individuals are most likely to leave a position and the actions most likely to circumvent that loss.

### **Approach**

Last year we began by surveying three samples: (1) a sample of military personnel that had just entered military service, (2) a sample of those that had completed at least one year, and (3) a sample of captains and lieutenants. Within each of these groups, we obtained responses from soldiers who were ready to leave the military and soldiers who were committed to staying in the Army. Although there were individual differences in the issues that affected their decisions to stay or leave, it was clear that issues related to job satisfaction were shared by most of the respondents. We were also able to obtain some suggestions from the respondents indicating what they felt would make a difference in their view of the military. We are currently preparing to replicate that sampling procedure with updated questions based on the data collected last year. Questions were revised to focus on the most salient problems found.

A model that incorporated two components to predicting satisfaction with military life was tested. This model allows for individual differences in dissatisfaction while predicting individuals' intentions to stay in the military. The prediction is based on the discrepancies between what they expected when entering the Army, what they experienced, and how they imagine the demands of a comparable civilian position. Initial study results with a relatively small sample looked promising and we are looking forward to replicating the tests using a larger sample.

We were also able to determine, using last year's samples, that the temporal discounting data for salary increases over 2 to 4 years replicated results obtained with civilian participants and those reported in the literature. We are currently working with this data to develop a detailed accounting of the preference structures for raises.

Also, we are currently preparing to replicate these findings using a civilian organization. Although we have been collecting some data from students, most of the students samples have expressed a strong preference not to enter the military service. By changing our focus to adults who have positions in a large civilian organization, we can compare their expectations and job related issues to the information we obtained in the military setting. Our analyses will focus on individual differences in preferences, concerns, and expectations that determine the outcome of decisions to seek jobs or change jobs.

### **Progress**

Since August 1, 2000, the following tasks have been completed:

1. I trained two students (Kristen Christy and Lisa Beasley) to assist in the data collection and preliminary analyses.
2. We began collecting data with civilians on their attitudes and expectations about civilian and military careers in October 2000. This pilot data was used to modify the surveys.
3. We completed preliminary descriptive analyses of the pilot data. We are adding to the civilian sample size and diversity this quarter using the revised surveys.
4. Kristen and I collected data at Fort Bliss on Feb. 5, 2001 and at Fort Hood on April 2, 2001. We completed the analyses. I reported some of the results we obtained to officers at ARI in August of 2001. I am currently finishing a technical report on these results.
5. I trained Loretta Hill to continue in Kristen's place. Loretta is collecting data at Los Positas College and the Business School to increase the male respondents in our sample before June.
6. Loretta and I will also be collecting data at Fort Bliss at the beginning of March and at Fort Carson in May.
7. Lisa has programmed the surveys on a Web Site and will be collecting data from organizations in about 1 month.

### **Contributions To Basic Science**

These studies will involve the development of new modeling and measurement techniques. By using Image Theory and Policy Modeling it will provide a test of the theories and extend information about decision making in the context of career decisions. Finally, we hope to generate survey instruments that can be used to measure peoples' attitudes toward work in a way that provides information on strategies to recruit and retain valued personnel. We also hope to include practical suggestions for changes that may improve retention.

### **Potential Applications**

The application of this work is relevant to any organization that recruits a work force, wishes to retain valued employees, and wants to anticipate when these employees are likely to look for alternative positions. The results from this research will identify motivational resources to assist in attracting and retaining talented personnel. In general, people are motivated when the compensation package meets their expectations (Vroom, 1964) and when they perceive that they are being treated equitably (Adams, 1965). By monitoring our participants' experiences and interpreting these experiences according to their expectations about the job and competing jobs, we can use this feedback to predict dissatisfaction and stimulate change.

## **Personnel Turnover and Team Performance**

**Contract #:** DASW01-00-K-0018

**Institutions:** University of Pittsburgh  
and Carnegie Mellon University

**Contract Dates:** 9/1/00-11/30/03

**PIs:** John Levine, Linda Argote,  
Kathleen Carley, & Richard Moreland

### **Scientific Objectives**

One of the most daunting challenges for work teams is personnel turnover. Personnel turnover in work groups is defined as the entry of new members and/or the exit of old members. This challenge is particularly critical in organizations, such as the Army, that must cope with downsizing and frequent personnel change. Turnover represents a change in team composition that can have profound consequences for team performance. It alters the distribution of knowledge within the team as well as relations among team members. Thus, how to deal productively with turnover is a critical question for both theoretical and practical reasons.

We propose that the impact of turnover is mediated by changes in the quantity, quality, and distribution of task-relevant knowledge within a team. Such knowledge, which can be conceptualized in several ways (Klimoski & Mohammed, 1994), can have an important impact on team performance (Argote, Gruenfeld, & Naquin, 2001; Cannon-Bowers & Salas, 1998). Personnel turnover has negative consequences to the extent that it reduces the total knowledge base of the team and/or members' ability to exchange knowledge efficiently. In contrast, turnover has positive consequences to the extent that it augments the team's knowledge base and/or members' ability to send and receive this knowledge.

In addition, we assume that the knowledge changes associated with turnover both influence and are influenced by social interactions among team members. When old members leave a team, typically depleting the team's knowledge base and disrupting well-learned patterns of knowledge distribution, remaining members must renegotiate their responsibilities for storing and sharing information. When new members enter a team, they must acquire specific knowledge relevant to their role as well as knowledge about others' competencies and responsibilities (Levine & Moreland, 1999). This socialization process can be quite challenging if newcomers must learn large amounts of information and old-timers do not transmit this information efficiently. In addition, newcomers may introduce useful changes in how the team performs its task (Levine, Choi, & Moreland, in press; Levine, Moreland, & Choi, 2001). This is particularly likely when the team is facing new challenges and newcomers possess task-relevant knowledge.

### **Approach**

The proposed research utilizes two team tasks (decision making and production) and employs two methodologies (laboratory experimentation and computer simulation). Three related lines of work are being conducted. First, studies using the experimental version of the decision-making task investigate how newcomers help teams adapt to challenges. In this research, team members use a computer network to obtain and share rapidly changing information in an airplane surveillance scenario. Second, studies using the experimental version of the production task investigate how teams limit the negative impact of newcomers on transactive memory systems (cf. Moreland, 1999; Moreland, Argote, & Krishnan, 1998). In this research, team members work together on a challenging construction project (i.e., building transistor radios). Third, our simulation work seeks to create a unified approach to turnover that

integrates work in the decision-making and production domains and extends our analysis to larger groups and longer time periods than can be readily investigated in the lab. The computer simulation studies are virtual experiments designed to match and extend both sets of laboratory experiments by adapting powerful computer programs (ORGAHEAD and CONSTRUCT) that have proven useful in modeling the performance and dynamic behavior of groups and organizations (e.g., Carley, 1991; Carley & Svoboda, 1996).

### **Progress**

During 2001, we made substantial progress on all three components of our research. An initial experiment using the decision-making task investigated how a team's level of choice in selecting a task strategy and subsequent performance using that strategy affected the team's receptivity to a newcomer-initiated innovation. The second study in this series, currently underway, examines how receptivity to newcomer innovation is influenced by the newcomer's confidence in his/her suggested change and the team's perception of the utility of its current strategy.

Our initial experiment using the production task investigated how expected and actual turnover affected team members' transactive memory and performance. The second study in this series, currently in progress, examines how information about newcomers' capabilities can mitigate the disruptive effects of turnover.

In our computer simulation work, we have developed computational models for simulating group performance in the decision-making and production task domains. We are running virtual experiments to (a) validate the models against experimental findings, (b) examine the impact of databases as substitutes for transactive memory systems, and (c) examine the effects of turnover in larger scale systems. Our initial simulation work involved creating ORGMEM (an extension of ORGAHEAD) to match the transactive memory experiments and conducting a series of virtual experiments using this simulation. We have subsequently developed an agentized version of CONSTRUCT, which has ORGMEM embedded in it, and used that to replicate and extend the transactive memory experiments. We have also extended the ORGAHEAD multi-agent network model and used that to explore how newcomers impact performance. We are in the process of replicating lab experiments in this area.

### **Contributions to Basic Science**

Only a handful of studies have examined personnel turnover in teams. These studies suggest that turnover typically disrupts team performance, but is more deleterious under some conditions than others (e.g., Argote, Insko, Yovetich, & Romero, 1995). Because these studies vary widely on conceptual as well as methodological grounds, their results are difficult to integrate in a theoretically satisfying manner. Therefore, a major goal of the present research program is to provide a stronger theoretical framework for understanding the consequences of turnover (positive as well as negative) for work teams. We believe our use of simulation in conjunction with experimental studies will be helpful in achieving this goal. The simulation studies will allow us to examine a wider range of parameter values than is possible in the laboratory, whereas the experimental studies will help us refine and elaborate the simulation models. In addition to clarifying the effects of turnover in teams, our research program will generate valuable information on how social and organizational scientists can work together in linking laboratory experimentation and computational analysis.

### **Potential Applications**

Collaborative work is an increasingly important aspect of organizational life, and many organizations assign their most critical tasks to work teams (Ilgen, 1999; Sundstrom, 1999). Unfortunately, however, teams do not always provide the benefits they promise (Hackman, 1990). Failure to adapt to personnel turnover is one reason teams' actual productivity falls below their potential productivity. Turnover can be harmful, for example, when a team loses a productive member and must expend time and energy training a replacement. But turnover can also be helpful, when a team loses an unproductive member and gains a replacement with valuable knowledge. Research clarifying the conditions under which turnover hinders versus helps team performance can thus make an important contribution to understanding and improving organizational effectiveness.

Our simulation work has other potential applications as well. For example, the new agentized version of CONSTRUCT can be used to examine simultaneous strategies for stabilizing one's own group/organization and destabilizing an opposing group/organization. For example, it can be used to look at the impact of (a) recruiting new members to one's group or increasing the commitment of current members and (b) isolating members of an opposing group (e.g., enticing them to defect, reducing their operational capability, or physically eliminating them; cf. Levine, Moreland, & Ryan, 1998). As such, this simulation is potentially useful for counter-terrorism studies.