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Special Report 13

Project Summaries: Office of Basic Research Contract Program, 1989—1991

Office of Basic Research

August 1990

United States Army Research Institute
for the Behavioral and Social Sciences

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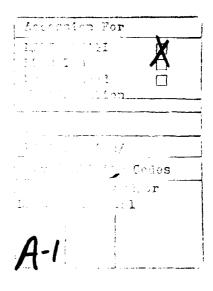
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency Under the Jurisdiction
of the Deputy Chief of Staff for Personnel

EDGAR M. JOHNSON
Technical Director

JON W. BLADES
COL, IN
Commanding

Technical review by

Michael Drillings

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			Human performance	Human factors	Learning

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This special report is a compendium of research contracted by the Office of Basic Research of the U.S. Army Research Institute for the Behavioral and Social Sciences in the period from 1989 to 1991. It includes reports and summaries in the field of the behavioral sciences which cover the topics of (1) group functioning, communicative processes, and organizational design, (2) human performance and naturalistic decision dynamics, (3) learning, cognition, and problem solving, and (4) special reports.

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1989—1991

Office of Basic Research

Basic Research
Michael Kaplan, Director

U.S. Army Research Institute for the Behavioral and Social Sciences
5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600

Office, Deputy Chief of Staff for Personnel
Department of the Army

August 1990

FOREWORD

The Office of Basic Research (OBR) in the Army Research Institute (ARI) is the locus of an ongoing collaboration between the world of behavioral science and the military community --an effort that makes available to behavioral technologists in soldier-oriented R&D the fruits of fundamental research into relevant aspects of human behavior. Its aim is to add new knowledge, methodologies and generalizable principles to many subdisciplines of behavioral science, laying the groundwork for innovative solutions to new and, as yet, unresolved people-related problems of substantial concern to the Army.

This collaboration has been brought about through an extramural Basic Research Contract Program managed by OBR. The present document summarizes the content and fundamental findings of the Program, and outlines its relationship to the Laboratories and applied research programs of ARI.

EDGAR M. JOHNSON
Technical Director, ARI, and
Chief Psychologist, U. S. Army

TABLE OF CONTENTS

INTRODUCTION

If the joy of science is discovery, it is the business of science to communicate these findings.

That is the primary concern of this document: to communicate fundamental scientific information about human behavior, which has been generated by extramural basic research contracts in the Office of Basic Research (OBR) at the U. S. Army Research Institute for the Behavioral and Social Sciences (ARI).

It is part of a broader OBR effort to make all of ARI's basic research more accessible to our fellow scientists, the military and academic communities, and others who have serious interests in the progress of behavioral science. That effort includes establishment in OBR of the Basic Research Archives and an electronic Basic Research Content Database, which will eventually make it possible for accredited users to access the files via modem from their desktop PCs. (These projects have been undertaken with the assistance of Research Fellows from the Consortium of Washington Universities.)

The reader will find in these pages summaries only of OBR contract projects ranging over the period 1989-1991. This contract program, however, is but one of many programs for which the Office of Basic Research has responsibility.

Among them are: In-House Basic Research, to be relaunched in FY 91; the Small Business Innovative Research Program; the National Research Council Resident Associate Program; an international behavioral science and technology watch; the S. L. A. Marshall Program --which includes an Honorary Research Chair and a Distinguished Lecturer Series; coordination of information on industry's Independent Research and Development program; a Summer Science and Engineering Apprentice Program; a graduate student research apprenticeship program --Consortium Research Fellows-- with the Consortium of Washington Universities; an intensive outreach effort to Historically Black Colleges and Universities and Minority Institutions; research support in behavioral science for the U. S. Military Academy; and a series of substantial projects in collaboration with the National Academy of Sciences.

OBR's official research mission is to "develop the behavioral science base for future applied research aimed at improving the effectiveness of soldiers and Army systems." It is a kind of way-station between the world of behavioral science and the military community. For even as it searches out the state-of-the-art in behavioral science, encouraging projects most likely to contribute generalizable scientific principles and new knowledge, it can only support efforts that have potential military relevance and likelihood of leading to behavioral technology.

1

In a word, <u>OBR</u> <u>sets</u> <u>the</u> <u>stage</u> scientifically <u>for</u> <u>new</u>
<u>behavioral</u> <u>technology</u>, facilitating the process by arranging to
transfer promising findings to its sister (applied) units within
ARI for exploratory development work. It is able to bring this
about, because of its integral position within the ARI structure
and within the ARI program.

ARI itself is a developing agency of the U. S. Army, and its
principal agency for soldier-oriented research and development
in personnel and training. Its mission is to maximize Army
effectiveness through research and development in the
acquisition, training, development, utilization and retention of
Army personnel. Its goal is always to apply research about people
to getting the best from our soldiers. Its organizational
mechanism for meeting these responsibilities is composed of three
major laboratories, each with a significant, well-delineated
segment of the ARI program. The laboratories and their major
research areas are noted in the following list:

Manpower and Personnel Research Laboratory

--recruiting, selecting, assigning and retaining
    soldiers

--Army organization, leadership and management at all
    levels

--decision-making in the Army personnel system

--predictors and measures of soldier performance

--family impact on soldier retention and readiness

Systems Research Laboratory

--best possible performance from the soldier
    functioning in the system

--getting the human element into system design

--understanding human capabilities and limitations

--improving decision-making in battlefield systems

--applying new technology to enhance total system
    effectiveness

Training Research Laboratory

--training in Army units

--specific basic skills required for successful
    performance

/ /

--training in Army schools

--cost-effective training methods and devices: for example, simulation, and improved applications of computer-based instruction

--specialized training for specific weapons systems

In setting forth its basic research program, OBR has established for Fiscal Year 91 three "core program areas," corresponding respectively to the set of applied research concerns listed for each of the three ARI Laboratories. These are shown in the following listing, together with subcategories identified by the OBR scientific staff as relevant, fundamental research foci in need of scientific elaboration.

Group Functioning, Communicative Processes, and Organizational Design

--Group Performance and Communication

--Group Problem Solving and Decision Making

--Leader-Group Relations

--Organizational Reliability Principles

--Foundations of Performance Prediction

--New Approaches to Manpower Modeling

Human Performance and Naturalistic Decision Dynamics

--The Motivation of Performance

--Human Chronopsychology

--Parameters of Stress-bound Performance

--Human Error Determinants

--Naturalistic Decision Dynamics

Learning, Cognition, and Problem Solving

--Advanced Concepts in Learning

--New Approaches to Problem Solving

--Long-term skill retention

A fourth category, Special Projects, encompasses unique innovative or creative efforts which do not fit within the core

areas or, as in the case of new methodologies, may have broad applicability extending across many subdisciplines of behavioral science.

In OBR's contract program, a Broad Agency Announcement is issued each year to solicit both exploratory (concept papers) and formal proposals relating to the announced program areas. In a given year, certain research foci of special interest may be highlighted in the Announcement. Notice of the set-aside program for Historically Black Colleges and Universities and Minority Institutions is also included.

Readers familiar with OBR contract research in earlier years will recall four program areas, viz., Organizational Design and Group Functioning; Behavioral Foundations of Systems Design; Decision Making and Problem Solving; and Acquisition, Maintenance, and Transfer of Skills.

The entire program was restructured for Fiscal Year 90 into three new core program areas and the Special Projects category, each with a series of sub-areas or foci. (These are substantially the same as the listing for Fiscal Year 91, shown above.) Atop each project summary are titles of the new (N) areas and the older ones (O) from Fiscal Year 89, for those who wish to track the reclassification.

Project summaries have been organized under the new headings in the sections which follow, each of which is described with a brief introduction. Within each section, the order of the summaries begins with completed contracts and ends with the most recent work.

The staff of the Office of Basic Research are always available for questions and discussion of our programs. For telephone inquiries, the number is (202)-274-8641 (or Autovon 284-8641). The door is always open, and we shall hope to meet you.

Michael Kaplan
Director,
Basic Research

Group Functioning, Communicative Processes, and Organizational Design

The Army is a hierarchical organization in which effectiveness is measured by and dependent upon group performance. Group performance is dependant on many factors such as communication, leader group relations, and decision making. If breakdown occurs in these processes, organizational reliability fails and ultimately the organization becomes ineffective.

Considerable savings would ensue, and organizational reliability would be substantially increased, if methods of performance prediction and organizational modeling were established which would allow identification of processes failures and decisions at critical junctures to change or improve organizational performance.

The goal of our research program in group performance, communicative processes, and organizational design is to understand variables and develop models to characterize and quantify group performance on tasks requiring coordination and shared resources. We are especially concerned to understand these processes in situations of crisis and stress. We seek to determine the role of experience and communication in building shared mental models and exploiting distributed knowledge in decision making and problem solving, to generate theories of group learning, to identify training procedures that enhance performance, and to understand performance in hierarchically organized groups.

(N): Group Functioning and Communicative Processes
(O): Organizational Design and Group Functioning

ENHANCING PERFORMANCE UNDER STRESS BY INFORMATION ABOUT ITS EXPECTED DURATION

Completed
DAJA 45-86-C-0048   11/86-11/89
University of Haifa   Shlomo Breznitz

SCIENTIFIC OBJECTIVES: Field experience suggests that knowledge about when a particularly stressful situation or task will end, may have significant impact on soldiers' ability to endure. This "tour of duty" phenomenon has been studied systematically. The main objective of this research is to analyze the effects of such information on endurance of stress in a controlled laboratory setting, as a prelude to field application.

APPROACH: The main laboratory paradigm is the Cold Pressor Test, which measures the ability to endure the pain of keeping one's hand in a bucket of ice water for an extended period. Endurance of physical exertion is studied by using the dynamometer test. Subjects receive either exact information about the expected duration of the task, or do not know when it will be over. Early discouragement and encouragement are produced by initial false information leading subjects to believe that the task is longer or shorter, respectively. This information is subsequently corrected, producing encouragement in the first case, and discouragement in the other one. The optimal timing of encouraging information, or of necessarily discouraging one is given special attention. In addition to behavioral measures of endurance, some psychophysiological and psychological measures are being obtained.

RESULTS AND CONCLUSIONS: If the task appears manageable, accurate information about its duration is best. When the task is perceived as too difficult, or too long to endure, performance can be enhanced by information management optimizing the costs and benefits of encouraging information. The timing of information is crucial, and depends on systematic analysis of the specific task, as well as ongoing indicators of endurance.

CONTRIBUTIONS TO BASIC SCIENCE: The study contributes to basic knowledge about cognitive and motivational control of behavior under stress.

POTENTIAL APPLICATIONS: Some of the effects found in the laboratory were pre-tested in the field using soldiers on difficult marches as subjects. Results indicate that endurance is significantly affected by the information parameters investigated. The research provides a rationale for information management in a variety of military contexts.

ARCHIVAL PUBLICATIONS:

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In: Breznitz, S. & Zinder, O. (Eds.), Molecular Biology
of Stress. Alan R. Liss, Inc.

(N): Group Functioning and Communicative Processes
(O): Decision Making and Problem Solving

A DISCOUNTING MODEL FOR FUTURE CONSEQUENCES

Completed
MDA 903-87-K-0627   9/87-8/89
Purdue University   Mary Kay Stevenson Busemeyer

SCIENTIFIC OBJECTIVES: The purpose of this research program is to develop a general model of how individuals make decisions that involve temporally remote or long range consequences. The primary focus of this project is to develop a systematic empirical foundation for a temporal discounting model that can be applied to a broad range of phenomena. The current research program has been designed to 1) determine if the assumptions of scale independence holds 2) extend the model to other types of response scales such as reaction times, magnitude estimation and tradeoffs, 3) determine how a series of events that extend into the future are discounted, 4) extend the model to a comparison of gains and losses, and 5) compare the effects obtained with other types of uncertainty, (such as probability) to those that are obtained with time in similar contexts.

APPROACH: A measurement model has been used as a framework for investigating the way subjects respond to long term positive and negative consequences. Each subject is assumed to use subjective values in assessing the value of these outcomes across time. The temporal discounting process is tested from a number of different psychological perspectives. The pattern of ratings obtained from subjects may vary according to the task or manner in which the responses were elicited. This phenomena has been termed "the response function" or "elicitation effect". For the general model, scale values are derived from each attribute, specific discounting functions are tested, and the response characteristics associated with the various rating tasks are defined.

RESULTS AND CONCLUSIONS: The current discounting model is a ratio function that has been replicated across several types of single outcome stimuli. First, it was shown that when a series of events are described as a temporal series, temporal discounting does not occur within the series or at the end of the series. Since this particular study used funding programs for college that were described as four-year programs even if funding was not extended to all four years, it was hypothesized that the lack of discounting was peculiar to this setting. Several additional studies using investments and loans were completed to assess the effect of putting outcomes in a temporal series. Temporal discounting was obtained with these stimuli but not within the series. Subjects discounted the investment returns and loan payments according to the total investment time. An additional study will be needed to determine if the discounting function for multiple events has the same form as the discounting function for single events.

A second study focused on the relationship between response scales. In this study, special designs were used so that the same set of parameters could be estimated for a rated evaluation and for the strength of preference. The same discounting operation described both response patterns but when the stimuli were compared, the discounting function changed form. The subjective values for the amount of the return and the time dimension became more extreme. For example, a three-year investment period seemed longer when compared to a one-year period than when evaluated alone. This study will appear in a special issue of <u>Organizational Behavior and Human Decision Processes</u>.

A study designed to test the assumption of scale independence was completed. In order to provide a more naturalistic risk factor, environmental problems were used as stimuli. Due to the complexity of the problem, individual differences in the perception of the seriousness of the problem requires individual analyses of the data. Preliminary results indicate that subjects responded differently to the solutions to environmental problems that were described as risky than those that were described as riskfree solutions. However, the difference in scale values did not occur across time frames or changes in the range of cost. This preliminary result indicates that scale convergence is not likely when outcomes that are perceived as risky are compared with outcomes that are seen as riskfree, but scale convergence does occur across different time frames.

A study that was designed to compare the impact of gains and losses in the future was completed. Tuition payment programs and lottery stimuli were used because of the interest value to the subjects and the ease of generating stimuli that were comparable on the gain/loss dimension. This data is currently being analyzed.

CONTRIBUTIONS TO BASIC SCIENCE: Although much attention has been devoted to risk analysis in the decision making literature, very little attention has been directed at describing the way individuals make decisions that involve future consequences. This research program was designed to investigate systematically the way subjects evaluate future consequences in a number of contexts. Time is viewed as another form of uncertainty that differs from "probability" since it is the utility of the outcome that is uncertain rather than the occurrence of the event. The primary contribution is an empirical foundation for describing future events and a theoretical model of how individuals deal with the future.

POTENTIAL APPLICATIONS: The results of this research have direct implications for recruitment incentive since the personnel are offered benefits that will not materialize until they have completed their tour of duty. This research also has direct implications for strategic planning. The measurement issues that have been described relate directly to methods used to assess the utility or attractiveness of incentives. Therefore, the content as well as the methods have potential applications.

(N): Group Functioning and Communicative Processes
(O): Organizational Design and Group Functioning

THE CONTRIBUTION OF GROUP MEMBERS' COGNITIVE RESOURCES TO THE EFFECTIVENESS OF SMALL GROUPS

Completed
MDA 903-86-C-0300   10/86 - 3/90
University of Washington   Fred E. Fiedler

SCIENTIFIC OBJECTIVES: This project seeks to identify the conditions under which certain cognitive resources, specifically, work-related experience and intellectual abilities of leaders and group members contribute to effective organizational performance. The project is primarily based on previous findings that stress with the immediate superior (boss stress) affects the utilization of the leader's "cognitive resources" (intellectual abilities and experience). Specifically, when stress is low, leaders tend to use their intelligence but not their experience; when stress is high, they use their experience but do not use, or misuse, their intelligence (low or negative correlations between leader intelligence and unit performance). The present project was designed in part to determine the reasons for these counter-intuitive findings.

APPROACH: Field studies and laboratory experiments examined the conditions which affect the successful utilization of cognitive resources, i.e., intellectual abilities, creativity, technical competence and knowledge gained from training and experience. The work included correlational studies to determine how leader and member abilities and characteristics correlated with performance under various conditions. Content analyses and observations of leader and member behavior were made under conditions of relatively low and high stress.

RESULTS AND CONCLUSIONS: (1) Intellectual contributions to management decisions. Previous research showed that boss stress strongly moderated the effective utilization of intelligence in decision-making jobs: Intelligence and performance correlated positively under low stress but negatively when reported boss stress was high (-.48 and -.47). Neither boss stress nor job stress strongly affected such leadership functions as communication and administrative duties. A subsequent experiment with ROTC cadets evaluated performance on the army in-basket exercise under conditions of low and high stress. Cadets' scores also were obtained for Horn's crystallized and fluid intelligence. We found that boss stress primarily affected the correlation between fluid (but not crystallized) intelligence and decision-making.

(2) The Behaviors of More and Less Intelligent or Creative Leaders Under Stress. A study of 54 ROTC 3-man teams investigated the processes responsible for the negative correlations between leaders' intellectual abilities and group performance. A content analysis of the typescripts showed that the more intelligent and creative leaders (a) tended to talk more, causing their group

15

members to talk correspondingly less, (b) produced fewer ideas, also causing their group members to produce fewer ideas. Lastly, (c) the more intelligent and creative leaders, as well as members of their groups, tended to "babble under stress".

(3) Contributions of technical training and leader directiveness to group decision-making. An experiment confirmed a hypothesis suggested by Col. Blades, ARI's commander, that job knowledge contributes to group performance only if the trained leader communicates the knowledge in the form of directive behavior. Conversely, training given to group members will contribute to group performance only if the leader is nondirective. Interestingly enough, members could not identify which leaders had received training.

CONTRIBUTIONS TO BASIC SCIENCE: The research contributes to Cognitive Resource Theory which identifies the role of cognitive abilities and knowledge of leaders and members into leadership theory. The theory indicates the interaction of specific situational factors and cognitive variables in affecting group and organizational performance.

POTENTIAL APPLICATIONS: Our research demonstrates that we can substantially increase the power of current selection procedures and training programs by specifying the conditions that must prevail if an individual's abilities of knowledge gained from training and experience are to contribute to organizational performance. The research thus has important implications for increasing the efficient utilization of currently available military manpower.

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Rogers, R.W., Lilley, L.W., Wellins, R.S., Fischl, M.A., & Burke, W.P. (1982). Development of the precommissioning leadership assessment program. Army Research Institute Technical Report 560.

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Zais, M.M. (1987). <u>Intelligence and academic achievement: The interactive effects of intelligence, interpersonal stress, test anxiety, and gender on academic achievement</u>. Doctoral dissertation, University of Washington, Seattle.

(N): Group Functioning and Communicative Processes
(O): Decision Making and Problem Solving

HANDLING DECISION PROBLEMS: A STRUCTURING LANGUAGE AND
INTERACTIVE MODULES

DAJA 45-84-C-0037
London School of Economics

Completed
10/85 - 9/88
Patrick C. Humphreys
Lawrence D. Phillips

SCIENTIFIC OBJECTIVES: Successful application of computer-based
tools and systems providing support for decision making have
hitherto been limited to handling low-level, well structured
problems in which the decision maker has little discretion in
formulating a policy for action. This research is designed to
identify and develop methods for provision of effective support
for higher level decision making where the use of decision
makers' own language in identifying and structuring problems is
of special importance.

APPROACH: This involves (1) the development of a framework for
specifying, assessing, interfacing and transporting modules in a
decision problem structuring library, (2) analysis of a number of
real-life high-level decision conferences, with emphasis on the
ways in which problems were formulated and structured, and
identification of ways where effective support could be provided
by analyst and/or computer based systems, (3) identification and
evaluation of methods for displaying and resolving differences in
the way decision makers represent decision problems through a
five level study of intuitive decision making by various
stakeholder groups (in the field of hazardous management). A
major characteristic of this research is that it is concerned not
only with the descriptive approach to decision making, which
attempts to establish what people do, but more importantly, with
what people can do when appropriately supported.

PROGRESS: (1) A catalogue of methods has been prepared
(Technical Reports 87-1 and 88-1). (2) An interpretation scheme
has been developed and used to identify, within material
generated from decision conferences, key themes and focuses of
concern being addressed by managers (Technical Report 87-2).
Analyses have then been carried out to see if these themes can be
related meaningfully to various features of the management teams
involved in the decision conferences (Technical Report 88-2).
(3) A five-level empirical analysis of stakeholder's intuitive
handling of decision problems within a domain, when constrained
at various levels, has been completed (Technical Reports 87-3 and
88-3).

CONTRIBUTIONS TO BASIC SCIENCE: The research conducted in this
project tests a theory that people's handling of unstructured
decision problems consists of five levels of subjective,
psychological problem structuring. A question addressed in this

research is the extent to which intuitive decision making is affected by setting constraints externally, at a particular decision making level. No previous empirical research on judgment and decision making has dealt with this problem.

POTENTIAL APPLICATIONS: (1) The catalogue and review of methods and tools for structuring and analyzing decision problems is useful in any application where a library of methods is being assembled in order to handle decision problems. (2) The results of the five level study have strong implications for the conduct of decision conferences and decision making situations where intuitive ideas of particular groups of stakeholders need to be developed and compared.

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(N): Group Functioning and Communicative Processes
(O): Organizational Design and Group Functioning

SOCIOLOGY OF ARMY RESERVES

Completed
MDA 903-86-K-0011   9/85 - 9/88
Northwestern University   Charles Moskos

SCIENTIFIC OBJECTIVES: The object of the research was to develop theoretical frameworks and expand databases for the sociology of the Army. The focal point was Army reserve components. The guiding principle is that social science generalizations based on active-duty military forces need to be reassessed when applied to reserve forces. The research focused on the differences, at both macro and micro levels, between organizations consisting of full-time members (i.e. active forces) and those made up of part-time members (i.e. reserve forces). The core characteristics of American Army reserve components were highlighted by an organizational contrast with active-duty components and by a comparative contrast with those of other Western countries.

APPROACH: The research project involved three phases. The first phase presented social background and survey data pertaining to reserve components. When comparable data were available, contrasts with active-duty components were drawn. In the second phase, findings were presented based upon in-depth interviews with reservists and participant observations within reserve units. The third phase highlighted organizational features in the American system by conducting cross-national comparisons with reserve systems in other Western countries. The comparative analysis was case-based rather than variable-based.

RESULTS AND CONCLUSIONS: Statistical data derived from social background variables and attitude surveys revealed: 1) The Guard and Reserves are more "top heavy" in grade distribution and are older than the active force. 2) The active force and the Reserves compared to the Guard are more highly educated and have both more minorities and females. 3) Prior service entrants in the Guard and the Reserves are much more likely to score higher in mental tests and be better educated than non-prior service entrants. 4) Dissatisfaction with service life is much higher in the reserve forces than in the active force. Rather than view the reservist as part of a moonlighting labor market, the data show that major disincentives arise from reserve duty conflicts with familial priorities and with released time from the civilian employer.

CONTRIBUTIONS TO BASIC SCIENCE: The research contributes to basic social science in two ways: substantive and methodological. Substantively, the research lays the groundwork for a sociology of reserve forces, hitherto an undeveloped subfield of military sociology. In effect, a subfield of sociology has been created.

Methodologically, the research adapts a "case-oriented" approach. Unlike the standard "variable-oriented" approach, the case approach

is not based on the language of hypothesis testing. Rather, the case approach treats cases holistically and attempts to deal with them not only in terms of their internal complexity, but also in terms of heterogeneity across cases. Whereas statistical methods (the mode of variable analysis) require both simplifying assumptions and a basic uniformity of units, comparative methods (the mode of case analysis) assume that casual relations are constantly confounded by "necessary" versus "sufficient" conditions. Qualitative binary methodology is used instead of quantitative multivariate statistics.

POTENTIAL APPLICATIONS: Recommendations are made to reduce MOS mismatch, to utilize "professional reservists", to reduce conflict between reserve duties and civilian employment, and to foster active Army recognition of reserve uniqueness. A standard policy should be to evaluate all personnel proposals emanating from active forces in terms of their impact on reserve forces.

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(N): Group Functioning and Communicative Processes
(O): Organizational Design and Group Functioning

PRIVATE SECTOR RESERVE SKILL COOPERATION

Completed
MDA 903-88-C-0400   11/87 - 5/89
Hudson Institute, Inc.   William F. Pierce

SCIENTIFIC OBJECTIVES: This study was designed to test private sector receptivity to participation with the Army in cooperation skill development and enhancement programs for reservists. Receptivity was measured against industry type and size, and, to a lesser extent, employers' perceptions of the military.

APPROACH: High-tech military occupational specialties (MOS) were selected from five battalions defined as "critical" from a Total Army perspective. These military skill demands were matched to industries with similar skill requirements. A survey of private sector employers from these industries were conducted to test private sector receptivity to a variety of Army initiatives designed to promote private sector-Army cooperation in developing or enhancing the skills of reservists needed by both sectors. Economic analyses of the battalion areas were conducted to highlight variables that might have influenced the private sector's receptivity (e.g. manpower supplies, compatibility of MOS to local economy) to such initiatives. Policy implications of these findings were developed for both general Army and battalion-specific policies.

RESULTS AND CONCLUSIONS: Five battalions were designated for the study by Headquarters Forces Command (FORSCOM). The survey instrument was developed and a review package was prepared for Office of Management and Budget approval to survey the private sector.

CONTRIBUTIONS TO BASIC SCIENCE: This study tested tools developed by the Department of Defense and civilian organization for matching military occupational specialties (MOS) to civilian job descriptions, and then relating these jobs to specific industries. Difficulties encountered in this process will lead to suggested changes and refinements in these tools.

POTENTIAL APPLICATIONS: Findings of this study will indicate whether or not private sector receptivity exists for cooperation with the Army in skill development or enhancement programs, specifically with respect to the five battalions under investigation. The findings may also highlight types of employers, by firm type and size, most receptive to pilot programs.

(N): Group Functioning and Communicative Processes
(O): Organizational Design and Group Functioning

SELECTION AND EFFECTS OF COMMUNICATION CHANNELS

	Completed
MDA 903-86-C-0172	8/86 - 7/89
Northwest Regional Educational Laboratory	Stephen Reder

SCIENTIFIC OBJECTIVES: This project seeks to extend our theoretical understanding of the variables underlying workgroup members' choice of communicative channels (e.g., face-to-face, written, telephone, electronic mail) and the effects of those choices on the behavior and performance of the workgroups. Previous experimental research on channel choice has had limited validity because subjects were not familiar with each other or the experimental task. Descriptive studies of channel utilization within real organizations, on the other hand, have tended to rely on self-reported rather than directly observed measures of communicative behavior. Neither the content nor the impact of communications through alternative channels has been available. The present research seeks to overcome these deficiencies and begin to model decision-making within communication activities.

APPROACH: The approach is observational. Workgroups within two selected organizations will be closely studied. Preliminary ethnographic studies will be conducted in each organization to provide background contextual information and to identify key workgroups from which to collect more structured data. Multiple procedures will be used to collect the more structured data, centered around a "shadowing" process in which observers follow and observe selected workgroup members for entire days at a time. Although not all members of workgroups will be shadowed, both shadowed and nonshadowed members will be asked on randomly selected days to keep logs of their communicative activities with specially developed instruments as a control on the impact of the shadowing on observed activities, and to enable generalization of shadowed activities to activities on other days and involving other workgroup members.

RESULTS AND CONCLUSIONS: Data have been collected from the first organization. Preliminary analyses suggest that: (1) individuals have widely varying preferences among face-to-face, telephone, hardcopy and electronic mail channels when all are available and being used by workgroup members; (2) channel selection is impacted by individual preferences, task characteristics and communicative strategies; (3) channel choices systematically affect both the content and structure of ensuing communication and group activities.

CONTRIBUTIONS TO BASIC SCIENCE: It is hoped that the eventual results of this work will be a theoretical framework for modeling channel-choice and impact in organizational communication. The model would specify effect of task and workgroup characteristics and individuals' communicative strategies on channel selection.

POTENTIAL APPLICATIONS: The preliminary findings suggest how military organizations could develop more effective workgroup communication and decision-making processes. Better communication, decision-support and personnel training systems can be developed from these findings.

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(N): Group Functioning and Communicative Processes
(O): Organizational Design and Group Functioning

THE CHANGING AMERICAN SOLDIER

MDA 903-86-M-7842
University of Maryland

Completed
9/86 - 9/88
David Segal

SCIENTIFIC OBJECTIVES: Our goal was to extend our understanding of constancy and change in soldier attitudes and values over time. Previous research has compared work related attitudes of soldiers in World War II and the 1970s. This research focused on soldiers' evaluations of their leaders, as a reflection of vertical bonding, in World War II and the 1980s.

APPROACH: The approach was to conduct secondary analysis of survey data collected by the Army during World War II and during the contemporary period. The World War II data were saved for posterity by ARI, which in the mid-1970s, invested in converting the original punched data cards produced by Samuel Stouffer and his colleagues to data formats compatible with modern EDP equipment. The contemporary data have been collected by Army contractors and Army agencies, as part of the evaluation of the unit manning system.

RESULTS AND CONCLUSIONS: An exhaustive screening of the World War II and current databases was completed, and survey items which are sufficiently similar in structure to modern items to justify comparison were identified. Strategic samples for analysis, identified by geographical area, unit, race, and historical period were also identified. Comparisons have been made, and a report has been written.

CONTRIBUTIONS TO BASIC SCIENCE: Substantively, this research increases our understanding of how much stability and change has taken place in the context of a specific organization, the U.S. Army, over a four-decade period. This enhances our understanding of organizational culture. Methodologically, the research provides a basis for exploring ways of dealing with some of the fundamental sources of bias (history, selection and instrumentation) in longitudinal research. Specifically, the research showed that in World War II, soldiers in elite units were more willing to serve under their officers and NCOs in combat than were soldiers in non-elite units. They also evaluated their officers more highly than their NCOs. In 1985, on the other hand, there was virtually no difference between the soldiers in elite (airborne) and no-elite units in this regard, and NCOs were evaluated somewhat more highly than officers in both elite and non-elite units.

POTENTIAL APPLICATIONS: Implications for the development of vertical cohesion as well as potential obstacles to vertical cohesion that have persisted through time or have increased have been identified by this research.

3.2

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(N): Group Functioning and Communicative Processes
(O): Organizational Design and Group Functioning

DEVELOPMENT OF UTILITY ANALYSIS MODELS FOR MANPOWER AND PERSONNEL DECISION MAKING

On-going

MDA 903-87-K-0001   12/86 - 11/91

Cornell University   John W. Boudreau, Sara L. Rynes,
Lee D. Dyer

SCIENTIFIC OBJECTIVES: This research will enhance our knowledge of the effects of models and information on managerial decision behavior, focusing on managerial decisions about programs to better manage employees at work. Previous research has focused on developing normative models and on comparing measures of isolated decision parameters, but there have been few studies to determine whether normative models accurately describe actual decision processes, whether information from normative decision models improves decisions, and whether the simplifications inherent in normative models create deficiencies serious enough to lead to poorer quality decisions.

APPROACH: The approach is to conduct research in field settings with actual human resource decision makers, using a variety of techniques including surveys, computer-aided programs, and interviews. First, a normative model of the decision is constructed through intensive interactive work with the principal decision makers, using available cost and benefit parameters. Next, the results of that model are presented to the decision makers, and the effects of the model on those decisions as well as noted deficiencies and enhancements are noted. Third, the consequences on uncertainty in the cost-benefit parameters are investigated through sensitivity analysis and survey research. Once critical parameters have been identified, assessments are made of the accuracy and reliability of those parameters to identify whether improved accuracy or reliability could contribute to reduced decision quality. Finally, the decision framework is used with a new set of decision makers to determine the effects of decision information on their decision processes. This approach allows us to extend the research to a new set of human resource management decision areas (e.g., compensation, employment stabilization, human resource strategy) that have not previously been addressed in cost-benefit analysis research.

PROGRESS: The results from two initial studies with managers and students suggest that managers reacted somewhat differently from students, and that the decision information had significant effects. We have also developed two computer-based decision support systems. These systems address the costs and benefits of compensation programs that make more compensation dependent on performance, and the costs and benefits of different strategic approaches to using a buffer work force to fill in during times of high labor demand.

CONTRIBUTIONS TO BASIC SCIENCE: Our research will help us learn how information affects human resource management decisions, and whether these effects are similar or different from decisions in other management areas. Moreover, it will allow us to understand better the role of human behavior and programs to change that behavior on the goals and objectives of organizations. Finally, it will help us understand the basic cognitive responses of decision makers to different types of information about human resource decisions.

POTENTIAL APPLICATIONS: This research will enhance the Army's understanding of both the types of cost-benefit information that can and should be used in evaluating, planning and communicating important decisions about manpower and personnel. Computer-aided decision tools, validated through cognitive research can make such decisions more efficient and more systematic.

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(N): Group Functioning and Communicative Processes
(O): Decision Making and Problem Solving

TEMPORAL DISCOUNTING: ASSESSING THE IMPACT OF FUTURE CONSEQUENCES

MDA 903-89-K-0224   9/89 - 8/91
Purdue University   Mary Kay Stevenson Busemeyer

SCIENTIFIC OBJECTIVES: The purpose of this research program is to develop a general model of how individuals use temporal information when evaluating outcomes and making decisions. The current data base indicates that a ratio discounting operation for time is used when single events are decribed in the future. When multiple events or a series of outcomes is presented, the discounting operation is associated with the end of the series but not with the components of the series.

APPROACH: A measurement model has been used as a framework for investigating the way subjects respond to long term positive and negative consequences. Each subject is assumed to use subjective values in assessing the value of these outcomes across time. The temporal discounting process is tested from a number of different psychological perspectives. The pattern of ratings obtained from subjects may vary according to the task or manner in which the responses were elicited. This phenomenon has been termed the response function or elicitation effect. For the general model, scale values are derived for each attribute, specific discounting functions are tested, and the response characteristics associated with the various rating tasks are defined. In the most recent studies, the parameters estimated using one type of task have been used to predict the responses in a different task that should be assessing the same discounting processes. Cross-task validation has been fairly successful and the methods have been useful for determining how strategies are affected by the evaluation and preference processes.

PROGRESS: The study that was designed to compare discounting functions for single and multiple events has almost been completed.

The study focusing on individual differences in discounting by comparing high school students, college students and adults over 30 years of age has been completed. The individual analyses have been started and should be completed soon.

A study that describes a method of using policy modeling to predict preference for labor contracts has been completed. This study provides a basis for extending the discounting model to a dynamic negotiation process model.

Two computer searches for a formal review of the current literature in temporal discounting have been completed.

CONTRIBUTIONS TO BASIC SCIENCE: Although much attention has been devoted to risk analysis in the decision making literature, very little attention has been directed at describing the way individuals make decisions that involve future consequences. This research program was designed to investigate systematically the way subjects evaluate future consequences in a number of contexts. Time is viewed as another form of uncertainty that differs from "probability" since it is the utility of the outcome that is uncertain rather than the occurence of the event. The primary contribution is an empirical foundation for describing future events and a theoretical model of how individuals deal with the future.

POTENTIAL APPLICATIONS: The results of this research have direct implications for recruitment incentive since the personnel are offered benefits that will not materialize until they have completed their tour of duty. There has also been some work that relates to negotiation. When enlisted personnel come up for reenlistment and must make that decision, it is a choice between what is offered in the service and what is available outside the service. Individual conflict resolution is similar to two party negotiation because the alternatives in both cases must tradeoff in order to find the optimal solution. This research also has direct implications for strategic planning. The measurement issues that have been described relate directly to methods used to assess the utility or attractiveness of incentives. Therefore, the content as well as the methods have potential applications.

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(N): Group Functioning and Communicative Processes
(O): Organizational Design and Group Functioning

FACTORS AFFECTING THE EFFECTIVE UTILIZATION OF INTELLECTUAL ABILITIES, TECHNICAL COMPETENCE AND EXPERIENCE IN ORGANIZATIONAL DECISION-MAKING

MDA 903-89-K-0193   10/89 - 8/92
University of Washington   Fred E. Fiedler

SCIENTIFIC OBJECTIVES: Cognitive Resource Theory investigates the conditions under which leaders' and group members' intellectual abilities, skills and knowledge contribute to effective leadership and organizational performance.

Current studies seek (a) to explain the unexpected finding that such conditions as stressful relations with superiors, evaluation anxiety, or nondirective leadership result in poorer performance by relatively more intelligent than less intelligent leaders, and (b) to improve personnel selection procedures and unit performance by more effective utilization of the abilities, knowledge and skills of leaders and group members.

APPROACH: Two laboratory experiments are in progress, both using 3-person teams of college students who perform decision-making tasks under conditions of low stress and mild stress induced by threat of evaluation by superiors. We obtain measures of intellectual ability, expertise and experience as well as video tapes for analyzing verbal and nonverbal reactions during group discussions. A third study examines data on military personnel, on how boss stress affects job knowledge, hands-on performance, and effective work in military units.

PROGRESS: 1. <u>Disfunctional leader behavior under stress</u>.
More intelligent leaders "babbled", i.e., they talked more but produced fewer substantive ideas than did relatively less intelligent leaders, and they also caused their group members to babble more than did less intelligent leaders.

In a subsequent follow-on experiment, fluid intelligence again correlated negatively with performance under stress while crystallized intelligence correlated positively with performance. Analyses of video-tapes also supported the hypothesis that stress distracted the more intelligent leader from the interaction with group members than was the case for the less intelligent leaders: under stress the more intelligent leaders smiled less, maintained less eye contact, and asked fewer questions than did less intelligent leaders.

2. <u>Effect of Leader Behavior on Utilization of Training</u>

A recently completed laboratory experiment shows that leader training was utilized only if the leader is directive, while group member training is utilized only if the leader was nondirective.

34

Group members were unable to identify the leader with more expertise (who had received training), a finding which has important implications for such concepts as Hollander's "idiosyncrasy credits", which relate leader expertise to leader status and performance.

3. Situation-Specific Prediction of Personnel Performance

We have shown that such conditions as boss stress strongly affects the effective use of cognitive resources by leaders and group members. If the task requires sound judgment and decisions, we find higher correlations between intelligence and performance under low stress than high stress. If the job involves rote and overlearned behavior, we find higher correlations between crystallized intelligence or experience and performance when stress is high.

For example, medical care technicians are expected to use their judgment in dealing with patients, and we find a correlation between a job knowledge test and their performance of high stress. In contrast, the job of infantry rifleman requires rote learning and application of overlearned behavior, and their AFQT scores correlate with job knowledge .34 (n-74,p<.01) under low boss stress.

POTENTIAL APPLICATIONS: We expect that our research will materially increase the potential power of selection and classification procedures as well as the utility of training by identifying (a) the conditions under which certain selection procedures provide the most valid predications, and (b) the conditions under which knowledge and skills acquired through training is effectively utilized. Perhaps even more importantly, if there is a reduction in military manpower, our research will suggest the more efficient use of personnel now members of the armed services. Our future research will seek to develop specific directions for developing the conditions that result in the fuller utilization of available personnel. We are currently searching for military units which will permit us to field test the methods that have emerged from our studies.

(N): Group Functioning and Communicative Processes
(O): Organizational Design and Group Functioning

SUCCESSFUL DECISION MAKING IN ORGANIZATIONS

DAJA 45-89-C-0037   1/90 - 12/92
University of Bradford, England   David J. Hickson

SCIENTIFIC OBJECTIVES: To elucidate some of the reasons for the
success or otherwise of strategic managerial decisions (decisions
such as a commitment to new equipment, a reorganization, a merger,
a relocation).

APPROACH: It is necessary to think through: (a) what are the
criteria of success (to be able to tell how successful a decision
was); (b) what may be some of the reasons for it. This initial
tentative conceptual delineation is using data already available,
and will continue in initial discussions with managers. The
project rests on a data base of records of 150 major decisions in
30 varied organizations in Britain, amassed during the late 1970's
and early 1980's. The data principally cover the processes of
reaching the decisions. The endeavour now is to trace what
happened afterwards; that is, how the decisions were implemented
and with what success. Since funds and time are limited, and as
some of those involved in the decisions will have moved on and
memories and records will have faded, it will not be possible to
trace all 150 cases: a minimum target is 50 in 10 organizations.
Fresh data will be collected by structured open-ended personal
interviews with senior executives.

PROGRESS: The first weeks of the project have been spent working
through the results of the prior study of 150 cases, and also of
subsequent snaller scale studies by PhD candidates of
implementation and of success. This has yielded a number of
concepts of success, (e.g., propitiousness: the decision solved
more problems than it raised; and achievement: what was done was
performed as intended) and some possible reasons for success.
Preparations have begun for the fieldwork which is planned to
commence in July, including the drafting of the viral access
letters and of sections of the interviewed schedule.

CONTRIBUTIONS TO BASIC SCIENCE: Ways of comparing the making and
implementing of one decision with another are rudimentary, and
improved concepts are needed to make this easier and more
comprehensive. The question then is,"Can what happens expain how
successful the decision turns out to be?" In brief, the aim is to
refine concepts of process in both the making of decisions and
their implementation, and also those of success.

POTENTIAL APPLICATIONS: (a) To suggest what criteria of success
can be applied; (b) to suggest what it is about making and
implementing a major decision that can raise the chances of
success; and (c) to suggest whether the criteria of success and
the reasons for it are more organization-related or topic-related

the reasons for it are more organization-related or topic-related (that is, whether they are peculiar to particular kinds of organization or to particular kinds of decisions, or are more general and therefore generalizable to military managerial decisions).

(N): Group Functioning and Communicative Processes
(O): Organizational Design and Group Functioning

ORGANIZATIONAL DESIGN: PROPOSED THEORETICAL AND EMPIRICAL RESEARCH

MDA 903-85-K-0404   9/85 - 8/90
University of Texas at Austin   George P. Huber
                                                 William H. Glick

SCIENTIFIC OBJECTIVES: The overall objective of the research is to improve social scientists' understanding of organizational design and administrators' ability to design more effective organizations.

APPROACH: Year 1: Initiate review and theory building manuscripts in seven areas related to organization design. Year 2: Create research design and instrumentation, and arrange for field sites. Years 2-4: Collect panel data from field sites. Years 3-5: Analyze data. Years 3-5: Publish results. This brief description of the management plan overviews the "scientific activities". During the first year of the study, the literature was used to identify theories relevant to under-standing organization design-effectiveness relationships and to aid in the development of two research instruments, an interview instrument and an organizational assessment instrument. In years 2-4, the interview instrument is used in interviewing the chief executive officers of over 100 organizations every six months, eliciting from them information about organizational changes and the antecedents to these changes. The profile instrument is used to obtain information on organizational attributes such as structure, strategy, environment, effectiveness, and decision processes. In years 4 and 5 of the research, resulting data are to be analyzed to address the basic research questions concerning the relationships between organizational design and effectiveness, capitalizing whenever possible on the longitudinal nature of the data.

PROGRESS: Eight review and theory building manuscripts have been accepted for publication in referred journals or books. Two others are under review for such outlets. Several empirical papers have been presented at the meetings of scientific societies. Some sample findings from these efforts are: (1) advanced information technologies are affecting organizational design, intelligence, and decision making in unintended but generally beneficial ways, (2) the information environment of organizations, a sample representation of the actual organizational environment and an input to the development of the perceived environment, holds much promise for the design of organizational intelligence systems, (3) the variable "media richness" is likely to become an important component of evolving theories of organizational learning, (4) the relationship between organizational centralization and effectiveness is generally negative and the commonly accepted beliefs that environmental turbulence and organizational size moderate this relationship are incorrect; further, methodological variables are the best predictors of findings concerning the

relationship between centralization and effectiveness, (5) the observed relationships between the technological and structural characteristics of organizations are largely predictable from methodological variables, and several commonly accepted moderator variables are not effective predictors of observed relationships, and (6) contrary to commonly accepted beliefs, the relationship between the extent of environmental determinism and the propensity for strategic action is positive, and its interaction is predictive of certain organizational behaviors and performance.

CONTRIBUTIONS TO BASIC SCIENCE: We expect to provide data that will give corrected and more complete insight into the antecedents and nature of organizational design and redesign, and the effects of these variables on organizational performance. Results to date include the findings that (1) propensity for strategic action is moderately and positively related to organizational performance, (2) organizational centralization is negatively related to organizational performance, (3) conventional thinking about the moderators of these relationship is frequently incorrect, and (4) decomposition of the construct of organizational performance leads to significant variations in its predictability.

POTENTIAL APPLICATIONS: Its changing environment is causing the Army to consider various forms of redesign. We hope to be able to provide guidance as to which forms of redesign will result in increased performance.

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(N): Group Functioning and Communicative Processes
(O): Organizational Design and Group Functioning

THE SOCIOLOGY OF THE ARMY NCO

MDA 903-89-C-0039   1/89 - 12/91
Northwestern University   Charles Moskos

SCIENTIFIC OBJECTIVES: The object of this research is to develop theoretical frameworks and expand bases for the sociology of the Army. The focal point is an examination of the Army Non-Commisioned Officer (NCO) corps. NCOs bear critically on virtually all of the central concerns in military social science including cohesion in combat groups, unit training and performance, leadership, personnel retention, career development, the military family and women soldiers.

APPROACH: The approach is threefold. In the first phase, social background and survey data pertaining to the NCO corps are presented. When comparable data are available, contracts are made with lower enlisted ranks and officers. In the second phase, findings are presented based upon in-depth interviews and participant observations with NCOs in units. The third and final phase highlights organizational features in the American system by conducting cross-national comparisons with NCOs in other Western countries. The research design is explicitly dynamic in order to incorporate developments originating in the environment external to the Army. These developments will be used to evaluate the changing social organization of the Army during the period of the research (1989-1991).

RESULTS AND CONCLUSIONS: The first task has been completed and is available as a technical report entitled "The Sociology of the Army NCO: A Preliminary Assessment." This report consists mainly of tabular data that present significant social and demographic trends pertaining to the NCO corps. The second task is in progress and is based mainly on field interviews with soldiers in Panama in the immediate aftermath of Operation Just Cause (January, 1990). These data have led to a provisional formulation of "short-duration combat," a concept to be developed in the forthcoming technical report. Planning is underway for the third and final task dealing with comparative analysis.

CONTRIBUTIONS TO BASIC SCIENCE: The research contributes to social science in several ways. (1) The research lays the groundwork for a sociology of the NCO corps, a hitherto undeveloped subfield in military sociology. The research also looks at the subcategory of female NCOs, and thus contributes to the sociology of sex roles. (2) The data already collected points to the need for a major revision in the dominant paradigm of the sociology of combat, a paradigm that deals with long duration conflict. Task two will develop the concept of "short-duration combat," thus contributing to a broader understanding of human motivation in situations of extreme stress. Variables (e.g., NCO leadership, unit cohesion,

primary groups, belief systems) specified in the extent literature will be reformulated.

POTENTIAL APPLICATIONS: The findings of the research will have direct bearing upon at least three contemporary Army issues. (1) The paradigm of "short-duration combat" will expand understanding of combat motivation in the kind of warfare that will most likely characterize American forces in the forseeable future. (2) The issue of the utilization of women in combat will be informed by the only data ever collected from women in combat theaters. (3) The issue of "downsizing" of the Army will be informed by research findings that focus on the catagory most affected by the impending reduction in force: NCOs.

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(47)

(N): Group Functioning and Communicative Processes
(O): Organization Design and Group Functioning

MANAGING SITUATION INDUCED STRESS IN GROUPS OF MARINES

Ongoing
DAJA-45-89-C-0029   9/89 - 9/92
Universidade Nova   O. G. Pereira
de Lisboa   J. Jesuino

SCIENTIFIC OBJECTIVES: Generate theoretically sound and
practical guidelines for leaders in management of stress and
cohesion in military units.

APPROACH: Rework and combine extensive data in hand from
previous research with military trainers and trainees with new
data to be collected from Portuguese combat veterans of the
African counter-guerilla campaign, bearing on leadership actions
in managing unit cohesion and situationally induced stress.

(N): Group Functioning and Communicative Process
(O): Organizational Design and Group Functioning

PROMOTING INDIVIDUAL AND ORGANIZATIONAL PRODUCTIVITY THROUGH PRACTICAL INTELLIGENCE: THE ROLE OF TACIT KNOWLEDGE IN PERSONAL AND ORGANIZATIONAL EFFECTIVENESS

MDA 903-85-K-0305   9/85 - 8/90
Yale University   Robert J. Sternberg
                                                Richard K. Wagner

SCIENTIFIC OBJECTIVES: This program of research seeks to investigate the nature, origins, scope, development and trainability of tacit knowledge--what one needs to know in a given environment in order to succeed but that is not explicitly taught. For example, to succeed as a business manager, one needs to learn organizational norms, priorities, strategies for product development and marketing.   But this knowledge is not usually explicitly stated, and what is explicitly stated often does not match the true organizational norms and priorities.   The manager needs to learn what the norms and priorities are.   The research will help us understand how this learning takes place and what forms the learning takes.

APPROACH: The scientific approach is three-fold.   First, we have developed scales of tacit knowledge relevant for selected occupations, such as manager and salesman. The questionnaires have been construct-validated through a variety of multivariate statistical techniques, such as factor analysis and multiple discriminant analysis.   Second, we are seeking a better understanding of how tacit knowledge is acquired in the first place.   In particular, we have developed a model of the learning process people use in real-world settings to pick up tacit knowledge.   Finally, we have shown that tacit knowledge is teachable.

PROGRESS: We have developed tacit-knowledge scales for managers, academic psychologists, salespeople, waitresses and college students. Some of our main findings are that tacit knowledge tends to increase with experience in a given domain; that tacit knowledge predicts managerial success about twice as well as does IQ, but is uncorrelated with IQ; that tacit knowledge tends to be correlated across domains (higher scores on tests for one occupation predict higher scores on tests for other occupations); that tacit knowledge is distinct from personality and motivational variables; that there seems to be a general factor for tacit knowledge (scores on tacit knowledge subscales are positively intercorrelated); and that tacit knowledge is teachable.

CONTRIBUTIONS TO BASIC SCIENCE: The main contribution of this research is the construct validation of a theory and a test to measure practical intelligence. The construct validation has shown that this construct can be operationalized, and is psychologically distinct from the kind of academic intelligence measured by

traditional psychometric intelligence tests. We have shown that practical intelligence can be measured in a variety of pursuits, and that scores on tests of it are well predictive of real-world performance.

POTENTIAL APPLICATIONS: The tacit-knowledge scales have three important applications. The first is for selection of individuals. For example, managers with greater tacit knowledge have been found in our past research to be more effective than managers with less tacit knowledge, so that tacit knowledge provides a relevant criterion for picking new managers, or for promotion. The second application is diagnosis. Supervisors can use subscale scores (managing self, managing others and managing tasks) in order to understand a person's strengths and weaknesses. The third is training. The results of our work will provide important bases for developing managerial knowledge and skills.

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(N): Group Functioning and Communicative Processes
(O): N/A

INTERPERSONAL DECEPTION THEORY: EXAMINING DECEPTION FROM A COMMUNICATIONS PERSPECTIVE

                                                              New
MDA 903-90-K-0113   7/90 - 7/93
University of Arizona   D. Buller
                                                          J. Burgoon

SCIENTIFIC OBJECTIVES: The research will investigate actual communications between deceivers, truthtellers and receivers to determine the distinguishing characteristics of their communication that denote deception.

APPROACH: First experiments focus on the role of the recipient of deception by assessing the strategies and reactions that they encode, how receivers and truthtellers react to the receiver's behavior, and the ultimate success of the deception. Other experimental work will employ real-time conversations.

(N): Group Functioning and Communicative Processes
(O): N/A

COORDINATING INFORMATION AND DECISIONS OF HIERARCHICAL-DISTRIBUTED DECISION UNITS IN CRISES

University of Iowa

New
9/90 - 9/93
G. L. Rose

SCIENTIFIC OBJECTIVES: The research will seek to better understand distributed decision making in groups under conditions of dynamic and ambiguous environments, high pressure, and poor communications.

APPROACH: Initial efforts will be to perform a meta-anaylsis of the past research in this area. In later work, a computer simulation will serve as the basis for the analysis of parameters that affect individuals, organizations and groups. Finally, a series of experiments will be used to evaluate the value of the previous simulation.

(N): Group Functioning and Communicative Process
(O): Organizational Design and Group Functioning

SHREDDING AND RESTRUCTURING ARMY JOB FAMILIES

New Start
The George Washington University   Joseph Zeidner

SCIENTIFIC OBJECTIVES: This research seeks to advance differential assignment theory by more thoroughly distinguishing among enlisted soldiers' jobs that have typically been combined into large clusters for classification purposes.

APPROACH: Applying various methodological techniques, the project will attempt to increase the efficiency of the Armed Services Vocational Aptitude Battery (ASVAB) by increasing the number of job families of Military Occupational Specialties (MOS). Such a procedure could provide a better linkage between soldier aptitudes and job assignments, resulting in dollar savings and increased organizational and soldier productivity.

Human Performance and Naturalistic Decision Dynamics

A problem common to both Army systems and organizations is that they are often not designed with consideration of the capabilities and limitations of the individual human beings who make them work. A poorly designed organization requires highly trained individuals of above average motivation and competence to function. In a poorly designed system, operators are required to possess more capability and to have more training than would be required otherwise.

Considerable savings would result if systems and organizations were designed, from the beginning, with a greater appreciation of the implications of design decisions on the required characteristics of the individual members and operators. To do this, however, we must have a better understanding of human behavior to generate principles that can be applied to design.

Our research program is designed to provide a scientific basis for the design of organizations and systems to maximize goal directed performance. In order to better understand human performance and decision making in real systems and organizations, research is underway on individual and group motivation, performance rhythms and chronopsychology, the effects of stress on performance, and the nature and determinants of human error.

(N): Human Performance and Naturalistic Decision Dynamics
(O): Decision Making and Problem Solving

THE ROLE OF DATA AND FEEDBACK ERROR IN INFERENCE AND PREDICTION

SCIENTIFIC OBJECTIVES: This research is an investigation of the impact of error in data on performance in a variety of tasks. While environmental uncertainty is universally acknowledged to influence performance in cognitive tasks, there is scant data on how it does so. Both the locus (input and feedback) and type (measurement vs. system failure, or SF) were manipulated. This latter and potentially very important form of error has received no attention in the scientific literature, probably because of the powerful error theory developed using Gaussian definitions of error.

APPROACH: Four different cognitive tasks, with variations of each, were used. One was the Multiple Cue Probability Learning (MCPL) task, which requires subjects to learn to predict one variable from a set of other variables. A second was Watson's 2-4-6 task, a widely used inference task. A third was the "pseudodiagnosticity" task developed at Bowling Green, with which we have shown that people make inferences based on inappropriate data. The fourth task involved a complex, computer-based "artificial universe" developed here and at Ohio State.

RESULTS AND CONCLUSIONS: Thirteen experiments have been conducted, with a total of over 1,000 subjects. People are quite good at handling measurement error, which after all characterizes the biological environment in which we have evolved. Some people are seriously disrupted by the all-or-none SF error, more characteristic of man-made systems.

CONTRIBUTIONS TO BASIC SCIENCE: The conceptual analysis of error types is original and fruitful. The experimental results show that performance in some, but not all, people is seriously disrupted by SF error, but we have done the types of experiments that would give us insight into what cognitive processes are involved. We believe that one key piece of the puzzle is people's inability to relate incoming data to more than one hypothesis at a time, but this does not explain the individual differences.

POTENTIAL APPLICATIONS: If susceptibility to SF error can be understood, catastrophic operator errors may be made less likely.

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(N): Human Performance and Naturalistic Decision Dynamics
(O): Decision making and Problem Solving

THE USE OF PROTOCOL ANALYSIS AND PROCESS TRACING TECHNIQUES TO INVESTIGATE PROBABILISTIC INFERENCE

SCIENTIFIC OBJECTIVES: When statistical information about what is likely to happen and imperfectly reliable information about what is now happening conflict, people tend to neglect the statistical information and rely on the unreliable information about the present situation. The goal of this research is to describe the process by which novices, as well as experts in probabilistic inference and experts in the substance of the problem, combine the two types of information. Understanding of both novice and successful inference processes will help us to teach strategies for correct reasoning, and design information environments that support accurate inference.

APPROACH: To investigate the strategies people use in making probabilistic inferences, novices and experts are asked to solve probabilistic inference word problems. Their answers, their choices of information, and their concurrent verbalizations are analyzed.

RESULTS AND CONCLUSIONS: Novices were asked to estimate the probability that a hypothesis was true in three probabilistic inference word problems. In each problem, they answered before and after the presentation of each of three types of information -- base rate, evidence, and reliability of evidence. Results indicate that the more recent information had a greater impact and that the novices neglect of base rate information is caused by a failure to distinguish between two conditional probabilities: the probability that particular evidence would be seen if a hypothesis were true $p(E/H)$, and the probability that a particular hypothesis would be true if evidence were seen $p(H/E)$.

Another study investigated whether subjects respond differently when presented with $p(H/E)$ information instead of the usual $p(E/H)$. Verbal protocols from undergraduates, mathematics graduate students, and insurance professionals are being analyzed to determine strategies used.

CONTRIBUTIONS TO BASIC SCIENCE: The technique of requiring answers after each possible subset of the probabilistic inference word problem information has allowed unequivocal elimination of the hypothesis that subjects completely ignore base rate. It also provides data for testing production system models of inference strategies. The technique of requiring subjects to justify their selection of information for use in answering the word problem has given a new type of process evidence pertaining to the confusion

of p(E/H) and p(H/E). The discovery that people respond using available numerical probabilities, but not verbal probabilities, introduces a new dimension into discussions of the generality of flaws in people's statistical reasoning.

POTENTIAL APPLICATIONS: Many military operational contexts require the integration of information about expectancies (prior probabilities that a hypothesis will be true) with uncertain information about what is happening at present. If the statistical information is neglected, it could lead to an excessive amount of "false alarms". If, as demonstrated here, the most recent information is given more attention, then the flow of information in operational situations should be designed so that base rate information is presented concurrently with or after the current information, so that it is not neglected.

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on Systems, Man, and Cybernetics, SMC-17, 753-770.

(N): Human Performance and Naturalistic Decision Dynamics
(O): Organizational Design and Group Functioning

OPTIMAL AVERAGING IN PERFORMANCE TESTS (previously titled State Variations In Automatic Processing)

	Completed
MDA 903-86-C-0145	5/86 - 9/89
Pennsylvania State University	Marshall B. Jones

SCIENTIFIC OBJECTIVES: The purpose of this research is to develop a methodology for optimizing the temporal stability and predictive validity of performance tests and to apply that methodology to Project A, computer-administered tests.

APPROACH: Performance tests differ fundamentally from knowledge tests. The unit of analysis in a knowledge test is an item and the order in which items are administered is arbitrary. The unit of analysis in a performance test is a trial and order of administration is not arbitrary, mainly because knowledge of results is difficult or impossible to obscure in a performance test. In target tracking, for example, a subject cannot help but know how close the cursor comes to the target. As a result, practice effects cannot be ignored in a performance test, even when the test is very short. In the present research, a performance test is treated as a task to be learned and test results are analyzed as individual differences in skill acquisition and retention. Classical test theory is also used.

RESULTS AND CONCLUSIONS: The first step in the analysis is "forward averaging." It begins with the subjects' scores on the first trial. Then each subject's scores on the first two trials are averaged, then the first three trials, then the first four, and so on until the last trial is reached. This series of averages is then correlated with the corresponding series of averages from retest or a criterion to be predicted. Oftentimes temporal stability or predictive validity increases up to an optimal average and then decreases. When such an optimum is encountered, it means that the test's temporal stability or predictive validity cannot be improved by lengthening the test. It also means that the test can be shortened (back to the optimum) without loss of stability or validity. If a forward optimum is not encountered, forward averaging provides a basis for estimating what the effects of lengthening the test on stability or validity would be.

"Backward averaging" is the reverse of forward averaging. It begins with the last trial of practice. Then each subject's scores on the last two trials are averaged, then the last three trials and so on until the first trial is reached. Both backward and forward optima can be used to improve a test's stability or validity without changing its length, by scoring for the optimal average. However, backward optima are more common than forward optima and are especially important in scoring for validity. When backward and forward optima both occur, algorithmic continuations can be specified for determining the single most predictive average of

contiguous trials.

POTENTIAL APPLICATIONS: Of the 10 Project A tests, two (Simple Reaction Time and Cannon Shoot) have inadequately low, 4-month temporal stabilities (~.5). Optimal averaging indicates that the stability of Simple Reaction Time but not that of Cannon Shoot can be improved by lengthening the test. It may be possible, however, to improve the stability of Cannon Shoot by administering the test in two separated bouts of trials. Four of the 10 tests predict performance on an Anti-Aircraft criterion task (r=.3-.7). The validity of all four could be improved by rescoring for the optimal average. Target Tracking 2 and Choice Reaction Time have forward optima and could be shortened without loss of stability or predictive validity.

ARCHIVAL PUBLICATIONS:

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(N): Human Performance and Naturalistic Decision Dynamics
(O): Decision Making and Problem Solving

ANALOGICAL DECISION MAKING

Completed

MDA 903-85-C-0327   7/85 - 7/88
Klein Associates Inc.   Gary A. Klein

SCIENTIFIC OBJECTIVES: The objective of this research is to extend our understanding of decision making as it occurs in natural settings, especially those characterized by real-time information processing, shifting goals, and situation assessments based on experience with similar events. The goal is to model the decision strategies of trained personnel and to investigate the effects of variables such as time pressure, group interactions, and levels of expertise.

APPROACH: A twofold approach has been taken in this three-year effort. In Years 1 and 2, field studies investigated how decisions were carried out by trained personnel performing their natural duties. Domains were selected that had a high potential to generalize to military command-and-control decision making. The field studies combined direct observations and a Critical Decision Methodology (CDM) to elicit information about the cues, goals, and option evaluation strategies used by these personnel. In Years 2 and 3, experiments were designed to test specific hypotheses generated by these field observations.

RESULTS AND CONCLUSIONS: Three CDM studies were carried out in three operational domains: urban fire ground command, wildland fire incident command, and tank platoon force-on-force exercises. These studies represent natural experiments in which the degree of time pressure, need for group communication and type of decisions varied. In the urban fire ground and tank studies, decisions made by "novice" and "expert" decision makers were directly compared. In the wildland fire study, two types of decisions were distinguished for which the commanders had relative levels of expertise. A study of the moves made by chess players at two levels of skill (master and class B) playing tournament games under two levels of time pressure was also carried out. Data have been collected comparing the on-going verbal protocols of decisions made by 12 expert and 12 novice fire ground commanders during two simulated incidents. A final study investigated the knowledge structures of expert and novice fire ground commanders and the relation between these structures and decisions made during simulated incidents.

CONTRIBUTIONS TO BASIC SCIENCE: The results of these studies have been used to support and extend a Recognition-Primed Decision (RPD) model of decision making. This model offers several important contrasts to current normative and prescriptive models. For example, we find little evidence for option evaluation strategies that rely on the concurrent comparison of options' strengths and weaknesses. Instead, experienced decision makers put most of their

73

effort into evaluating and classifying a situation. Once the critical elements of a situation are recognized, a single option is generated (based on a typical reaction or learned operating procedure). This option is then evaluated for workability in the present case. Only in cases where this initial option is judged to be implausible is a second option generated, and then evaluated for plausibility. This process continues in a serial fashion until a workable option is found.

Several findings have emerged that have theoretical implications:

a. The RPD strategy minimizes calculational burdens on the decision maker, as well as maximizing the speed with which a decision may be implemented.

b. Experienced decision makers spend more effort in situation assessment activities, whereas novice commanders tend to generate more options and concurrently evaluate them.

c. Experts evaluate an option based on predictions about the future more than novices.

d. Analogical reasoning is not explicitly used as frequently as was originally hypothesized. However, when used, direct analogues serve important functions: clarifying situational dynamics, generating options in non-routine situations, and judging the probable success of implementing an option.

e. Schematic or prototypical knowledge is a more important determinant of skilled decision making than current models suggest.

f. Time pressure does not affect the quality of decisions made by experts as much as novices. This finding supports the validity of the distinction between "recognitional" and "analytical" decisions, and suggests that some types of decisions may be made as well under extreme time pressure as they would by following analytic prescriptions to generate and analyze multiple options.

POTENTIAL APPLICATIONS: Because the RPD model focuses on the importance of situation assessment in decision making rather than option generation and evaluation, it has direct implications for decision support and training needs. For example, the need to "de-bias" decision makers may be an artifact of laboratory tasks that use relatively static and novel problems. It may also be counterproductive to follow doctrine to generate and evaluate multiple options at the same time, especially for experienced personnel making decisions for which they have an experience base.

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(N): Human Performance and Naturalistic Decision Dynamics
(O): Decision Making and Problem Solving

THE ROLE OF EXPERIENCE IN NATURAL PROBLEM SOLVING: BASIC RESEARCH AND IMPLICATIONS FOR INSTRUCTION

SCIENTIFIC OBJECTIVES: We have investigated the roles of experience in problem solving: (1) the processes involved in case-based reasoning, a process of transferring the results of previous episodes to resolve new problems; (2) the triggers for and processes involved in learning from failures and successes in problem solving; and (3) the organization and processes incumbent on a memory for experience that can support such processing. Our investigation was in the context of automobile malfunction diagnosis. Our goal was to explicitly state the processing that happens during and as a result of problem solving experience.

APPROACH: Our approach had three parts. Protocol collection and analysis allowed us to elucidate the reasoning done by car mechanics during diagnosis and the knowledge and knowledge structures they use. It allows us to discover what mechanics at various levels of expertise know, and as a result of that, what the learning processes need to learn from experience.   Our second method, implementation of a computer program that can diagnose car malfunctions and learn on the basis of its experience, has allowed us to test hypotheses derived from protocol analysis with the specifics we find are necessary to make the program work as a person does. Our third method was additional experimentation on people to test if the hypotheses we have derived by the first two methods are valid.

RESULTS AND CONCLUSIONS: Protocol studies run during the first year and evaluated in the second year, showed that there are three major kinds of knowledge being used by mechanics at all levels: a causal model of how the car works and malfunctions, a set of indices that associates symptoms with possible faults and that allow a reasoner to index into the model at appropriate points, and a process model of the way troubleshooting is done.   We have identified several differences between novices and experts. Novices have little detail in their causal models, few indices into the model, and a naive model of the troubleshooting process. The causal models of more expert mechanics, on the other hand, show better understanding of the connections between the parts of the car and the hierarchical nature of the car's symptoms, indices are ɪ   e numerous and accurate, and the troubleshooting process is better known. We also noticed the differences in learning behavior. Novices tend to reorganize their knowledge with experience while, for the most part, experts fill in gaps in their knowledge. We identified several learning processes: learning by understanding explanations, active gap filling (actively seeking information

discovered to be missing), failure interpretation, absstraction, and case-based reasoning. We also identified under what circumstances mechanics tended to retain their experiences: when an experience was unexplainable, when it provided the first introduction to some concept, and when a serious mistake was made.

Based on the reasoning done by our subjects, we have built several experimental computer programs. The first, called LBUE, models the process of learning by understanding a teacher's explanations. It implements a process model in which the reasoner adds to his casual model by bridging small gaps in his causal knowledge based on the assumption that "if the teacher says it, then it is right". Depending on what it already knows, LBUE learns different things from a teacher's explanations. After learning, it does a better job of diagnosis. A second program, called CELIA, uses a combination of its casual model and its troubleshooting model to diagnose and learn from a teacher's explanations. Like LBUE, what it learns from the teacher depends on what it already knows, and once it learns, its diagnoses become better. A third program, called CORA, is a reconstructive memory model that is able to take a partial description of a situation and fill in details. It uses conditional probabilities to make its predictions.

As a prelude to running experiments to test out the predictions of our protocol studies, we have completed four tasks: (1) creation of an instruction tool called MECH that can be used to run experiments to find out more detail about what people are learning and what instructional methods work best in teaching those things, (2) derivation of methodologies for using the tool in experimentation, (3) derivation of dimensions to be tested and metrics for measuring learning in those dimenstions, and (4) a set of pilot experiments for testing the methodologies and metrics. MECH has the potential to serve several functions. It provides a simulation environment for problem solving, including graphics and help facilities. Thus, with the right knowledge in it, it could be used by students to practice what they have learned without the need for the particular device they have learned about being available. It provides an environment for teaching. It has facilities for providing feedback, for providing explanations to students, and for choosing problems to work on. It could therefore be used as a teaching tool. It provides an environment for experimentation. It records key strokes and keeps track of latency times. It also allows for different kinds of teaching/learning situations to be set up, thus allowing an experimenter to evaluate the differences between several different teaching strategies.

CONTRIBUTIONS TO BASIC SCIENCE: This work addresses the issue of what constitutes the distinction between a novice and an expert problem solver. It will help us explain natural interactions between learning and problem solving, the role of the teacher in facilitating learning from problem solving experience, and strategies for using examples in teaching.

POTENTIAL APPLICATIONS: There are several potential applications of this work, both in educational technology and automated systems. From the point of view of educational technology, there are three potential applications: (1) the creation of intelligent instructional systems that interact appropriately with a student (based on the student's knowledge state), and that tailor lessons to each student, (2) the creation of example-based teaching strategies that can be used by a teacher or a tutoring system, and (3) the creation of guidelines for teaching and textbook writing that present materials in ways that students can digest them. From the point of view of intelligent systems, in addition to creating tutoring systems, this work provides the basis for creation of expert problem solving systems that can become better problem solvers based on their own experience.

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(N): Human Performance and Naturalistic Decision Dynamics
(O): Decision Making and Problem Solving

LAY UNDERSTANDING OF PRINCIPLES OF ECONOMIC CHOICE

MDA 903-89-C-0022
University of Michigan

Completed
4/89 - 3/90
Richard E. Nisbett
James Morgan

SCIENTIFIC OBJECTIVES: The purposes of the research are (1) to determine the nature of the rules of choice that lay people use in making decisions in everyday life, (2) to determine whether new rule systems, more nearly in line with normative theory, can be substituted for lay systems, and (3) to collect evidence concerning whether use of more normative rule systems is associated with better outcomes.

APPROACH: Methods of approach include surveys and interviews intended to reveal the nature of the rule systems subjects use and experimental interventions intended to teach new rule systems.

RESULTS AND CONCLUSIONS: (1) Economists are more likely than noneconomists to use normative rule systems for choices that they make in everyday life, and for institutional decisions that they might be expected to play a role in. (2) Even relatively brief instructional sessions can change the rules that people apply at least to particular bounded classes of economic decisions (for example, decisions involving sunk costs, where expended resources cannot be retrieved). These sessions produce effects on choices with a duration of at least one month. (3) Use of more normative rule systems, especially for noneconomists, is associated with better financial outcomes. Biologists and humanities professors at the University of Michigan who reason more in accord with normative theory have higher salaries and higher recent raises, than scholars who use normative theory less.

CONTRIBUTIONS TO BASIC SCIENCE: The work indicates that decisions can be improved substantially by instruction in normative rules for choice. This has substantial implications for theory of reasoning. Some theorists have proposed that reasoning takes place by means of content-specific rules only. Others have proposed that abstract rules cannot be taught in such a way that they affect reasoning in everyday matters. The present work indicates both views are mistaken.

POTENTIAL APPLICATIONS: The work has applications all the way from designing appropriate secondary education curricula to creating interventions for managers. The fact that intervention programs have an effect on institutional choices has clear relevance to the military.

(N): Human Performance and Naturalistic Decision Dymnamics
(O): Decision Making and Problem Solving

EXECUTIVE DECISION MAKING PROCESS

Completed
DAAA 09-85-G-0035/0042   9/87 - 10/88
Horizons Technology, Inc.   E.C. Pence

SCIENTIFIC OBJECTIVES: The objectives of this research were to
analyze existing Israeli Defense Force data to develop a
descriptive conceptual framework and a simulation of senior level
decision making process in stress situations.

APPROACH: Based on the results of a literature review and existing
knowledge, a conceptual model was deveoped to guide the reseach
design and data collection. Next, a strategy for the collection
and reduction of existing data was developed. Analyses of existing
data were conducted to provide case studies of the individual,
organizational and environmental/situational factors impacting on
senior decisions made at critical points in the Israeli events.
A summary of the factors relevant to the executive decision making
process identified across case studies was prepared. The model was
be evaluated to identify the data required for the development of
the senior leader decision process model and simulation.   A
research design was developed and data were collected from both
American and Israeli senior leaders in the military, government
and private sector.

RESULTS AND CONCLUSIONS: A literature review was conducted and a
tentative schema for the content analysis of decisions of Israeli
military commanders under combat situations was developed. Four
case studies from Israeli-Arab conflicts were analyzed within the
context of the developed schema.   The pre-test demonstrated
successfully the applicability of the proposed schema.

CONTRIBUTIONS TO BASIC SCIENCE: The current research will develop
and validate a conceptual model that will advance the understanding
of the senior leader decision making process in stress situations.

POTENTIAL APPLICATIONS: The decision making model will be
developed for specific application for senior leaders in formal
organizations.   The simulation that will result from the model
development effort will have applications for the identification
and development of senior leader decision making processes in
stress situations in the military, government and private sector.

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(N): Human Performance and Naturalistic Decision Dynamics
(O): Organization Design and Group Functioning

PSYCHOLOGICAL ANALYSIS OF COURAGEOUS PERFORMANCE IN MILITARY PERSONNEL

	Completed
DAJA 45-87-C-009	12/85 - 12/89
University of British Columbia	S. J. Rachman

SCIENTIFIC OBJECTIVES: To gain an increased understanding of the nature of courageous performance, and how it can be promoted.

APPROACH: Military personnel who have to perform hazardous duties are studied before and after training, and during operational duties, or under laboratory stress. Various measures are used to assess their behavior, subjective reactions and psychophysiological responding. The bulk of the research has been carried out on military bomb-disposal operators.

PROGRESS: A number of interesting and potentially valuable findings have emerged. These include: confirmation of the significant and positive psychological effects of the training procedures, the cumulative effects of active duty on levels of confidence and skill, the psychological differences between experienced and inexperienced operators, the psychological problems that arise during operations, the after-effects of a tour of active duty, and so on. In addition, we determined that most operators performed fearlessly on virtually all missions, and that during the 4-month tour of duty their mood states were stable. A psychometric analysis of a group of operators who received decorations for gallantry revealed some differences in personality between these soldiers and another highly competent group of operators. The probability that there is a small group of soldiers who are especially capable of carrying out dangerous tasks fearlessly, was strengthened by a psychophysiological study of reactions to stress.

We found some (physiological) differences between decorated operators and non-decorated operators, who were in turn less reactive to stress than civilian control subjects. The potential importance of this group of soldiers, who are physiologically low reactors and unusually healthy, is considerable. Confirmation of these results encourages the hope that we can develop methods for identifying these people in advance, and perhaps choosing them for the commission of particularly hazardous tasks.

A prospective study of 28 bomb-disposal operators has now been completed, and using a discriminant function analysis, it was possible correctly to classify all of the decorated operators.

An investigation of the hypothesis that a positive attributional style promotes courageous behavior was conducted on two groups of soldiers. The hypothesis was not supported.

CONTRIBUTIONS TO BASIC SCIENCE: The project is directly relevant to basic research on the psychology of affect and cognition, with special reference to our understanding of the nature of fear. The research on courage is pioneering; there are no other experimental analyses of courage.

In addition to studying fear and courage as subjects of independent interest, I am attempting to link the two phenomena. The scientific significance of the research is explained at length in the Revised, Second Edition of Fear and Courage, to be published early next year by W.H. Freeman, Inc.

POTENTIAL APPLICATIONS: The research may improve our ability to identify people who are likely to perform courageously, and lead to improved training methods for promoting courageous performance.

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(N): Human Performance and Naturalistic Decision Dynamics
(O): Decision Making and Problem Solving

EVOLUTIONARY DECISION MAKING

MDA 903-86-C-0332

Decision Science Consortium, Inc.

Completed
9/86 - 9/89
Martin A. Tolcott

SCIENTIFIC OBJECTIVES: The objective is to extend our theoretical understanding of human decision behavior in evolving situations. Most decision models and theories have been based on relatively static experimental scenarios. This research focused on more realistic decision situations that evolve gradually, where unanticipated events may occur, options may change, previous decisions may have unexpected consequences, and even goals may change. The aim was to model the behavior of trained personnel and to investigate the requirements for, and effectiveness of, decision aids and training innovations for this type of situation.

APPROACH: The approach was to conduct experiments with trained Army personnel using simulated evolving battlefield scenarios. Participants were asked to make preliminary decisions based on early information, and then to reconsider their decisions in the light of new information, some of which supported and some of which contradicted the earlier decisions. Major interest focused on how early decisions affected the cognitive processing of the new information. Potential performance benefits to be gained from decision aiding and training innovations were estimated and tested experimentally.

RESULTS AND CONCLUSIONS: An initial experiment with intelligence analysts at Fort Huachuca showed that, even though participants differed in their early decisions, their initial confidence was high and tended to increase despite the fact that they all received identical new information. Confirming evidence was actively sought and was regarded as significantly more important than disconfirming evidence. Graphic/intuitive approaches were more common than tabular/analytic ones, and base rates were usually ignored in dealing with uncertainties. These findings were generally confirmed in observations made during field exercises at Fort Carson.

In a second experiment at Fort Huachuca, participants were given a brief description of typical decision biases and were provided with graphic aids to facilitate their handling of uncertainties (unlocated enemy units, association of enemy equipment with units, events associated with alternative enemy courses of action). Preliminary data inspection showed a generally lower level of confidence and much more willingness to reverse early decisions based on new evidence. Half of the teams (5 out of 10) changed their initial judgment at least once during the exercise. The tendency to overweight the importance of confirming evidence, although not eliminated, was significantly reduced.

The third experiment used the same basic scenario and instructions as those used in the first two, but now investigated the effects of analysts' early judgments on their selection of hypothesis-testing indicators. The results showed that in testing early hypotheses, analysts initially selected indicators that, if found, would tend to confirm their hypotheses, rather than select the most diagnostic indicators. However, in the face of balanced feedback, their confidence remained constant, rather than rising, as it had in previous studies in which they were the passive recipients of new information. This suggests that more attention is paid to contradictory evidence when the indicator is selected in advance for its judged importance. Moreover, subsequent hypothesis-testing strategies were more balanced.

CONTRIBUTIONS TO BASIC SCIENCE: The research provides evidence that trained Army personnel, working in their area of expertise, can show decision biases similar to those found in less realistic laboratory tasks. The research also seeks to develop a theory of decision making under evolving conditions.

POTENTIAL APPLICATIONS: Implications have been developed for decision aiding through more extensive use of graphics, procedures that emphasize disconfirming information and alternative possibilities, and training innovations.

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(N):   Human Performance and Naturalistic Decision Dynamics
(O):   Decision Making and Problem Solving

COGNITIVE FACTORS IN COMPUTER-AIDED DECISIONS

MDA 903-89-C-0134   5/89 - 5/92
Decision Science Consortium, Inc.   Leonard Adelman

SCIENTIFIC OBJECTIVES: The objective is to further extend our theoretical understanding of human decision behavior by trained personnel in complex, evolving situations. Moreover, we want to ascertain whether knowledge about cognitive heuristics and biases has practical significance for improving computer-aided decision making and, more generally, the design of decision aids.

APPROACH: The approach is to: (a) identify characteristics in a military task(s) that would seem to promote cognitive biases of various types and that might be amenable to reduction by computer-based aids or training; (b) perform experiments with trained personnel performing these tasks to determine whether the biases do, in fact, exist and whether they significantly affect performance; (c) if they do, design "decision aid features," and test the extent to which they improve performance; and (d) integrate research findings and move toward theoretically and empirically based recommendations for decision-aid design.

PROGRESS: We are approximately three-quarters through the first year and we have completed most of the data analysis for our first experiment. This experiment investigated whether the order (i.e., sequence) and manner with which the same information was presented to Army air defense operators significantly affected the probability estimates they provided when classifying unknown aircraft as friendly or hostile. On the average, order had an effect when information was presented sequentially (i.e., one item at a time), but not when information was presented globally (i.e., all at once). However, this effect accounted for a small proportion of the total variation in the participants' responses (R^2). More generally, all significant effects, including presentation or order, accounted for less than 10% of the total variation in the subjects' responses. Examination of the data for individual subjects shows substantial variation, both between-subjects and within-subjects, in their susceptibility to the order effects. These individual differences suggest limitations (and perhaps inadequacies) in current theories attempting to explain order effects in information processing.

CONTRIBUTIONS TO BASIC SCIENCE: The research showed that trained personnel working in their area of expertise can show decision biases similar to those found in realistic laboratory tasks. However, the small R^2s and large individual differences we observed suggest limitations in our theoretical basis for predicting the effects of order in information processing.

POTENTIAL APPLICATIONS: The results have potential implications for training air defense operators, the role of the human in future Army air defense systems, and the development of expert system components for these systems.

(N): Human Performance and Naturalistic Design Dynamics
(O): Behavioral Foundations of Systems Design

THEORIES, METHODS, AND TOOLS FOR THE DESIGN OF USER-CENTERED COMPUTER SYSTEMS

SCIENTIFIC OBJECTIVES: Modern high-functionality computer systems are difficult to master and use. Our project tries to establish a program of research that combines fundamental theoretical work on the cognitive processes involved in computer use with the development of innovative systems that embody new design approaches. The goal of this research is to gain an understanding of the design, implementation, and evaluation of Personal Information Environments.

APPROACH: Our work is based on the following duality: (1) User-centered system design cannot be done and understood without trying to test existing systems, extend them and design new ones; (2) user-centered system design cannot be understood by just doing it; the system building efforts must be based on a good understanding of the theoretical issues behind them. This duality requires an evolutionary approach towards system design and evaluation. During this evolution it is inevitable that our integration of research at the conceptual level leads to an integration of research at the system building level. In this manner we approach our goal to design, implement and evaluate customizable Personalized Information Environments. Theses systems instantiate our progress in achieving our goals, and raise theoretical and psychological issues that provide new research topics to be investigated in future work.

RESULTS AND CONCLUSIONS: The situation model is a mental representation of the situation as the user sees it, including the problems motivating a task, general ideas for finding a solution, and a characterization of the desired goal state. The system model cons:sts of a set of operations that, when invoked, would result in the desired solution. At the level of the situation model, goals refer to actions and states in the user's problem space and are articulated in terms of what they want and know.

HELGON (modeled after ARGON and RABBIT) is based on psychological theory of human memory [Fischer, Nieper-Lemke, 1989]. The major assumption is: locating information in a large space is an incremental activity characterized by many reformulations (based on critiquing of examples) carried out as a cooperative problem solving process.

RETRIEVE was developed in order to investigate the application of associative retrieval techniques in a query by reformulation environment [Fischer et al, 1989]. Evaluation of users of HELGON

showed that a large number of failures in retrieval were due to users not specifying the correct retrieval key words [Foltz, kintsch, 1988]. Using a spreading activation process based on human memory retrieval, RETRIEVE retrieves information based on semantic similarity rather than just direct keyword matches.

CODEFINDER is an attempt to explore retrievability problems in software design and reuse [Fischer, Henniger, Redmiles, 1990]. It extends HELGON with inductive information retrieval techniques based on associative data models developed in the Retrieve system.

INFOSCOPE is a system which helps users to cope better with the large, poorly structured information space available through the News program on computer networks [Fischer, Stevens, 1990]. the evaluation of the HELGON system led to an understanding that systems of HELGON's nature require rich structure in their underlying data model. INFOSCOPE investigates the relationship between the cost of adding structure and the perceived benefit to users of adding that structure. This should lead to an understanding of the technologies necessary to implement an integrated environment in which the technologies developed in the INFOSCOPE system work towards creating structure for the HELGON/CODEFINDER component of the environment.

EXPLAINER is a system which supports reuse by allowing users to get explanations of program examples selected from a catalog [Fischer, Henninger, Redmiles, 1990]. In the case of software components, users must sufficiently understand what the, have retrieved in order to incorporate items into their current work.

NETWORK is a simulation of how users retrieve their knowledge when doing routine computing tasks involving the file and mail systems [Mannes, 1989]. Using an associative network of a user's system knowledge, the model succeeds in modeling the performance of a meansends planner. The model permits of difficulties in planning computing tasks such as dealing with conflicting subgoals.

CONTRIUTIONS TO BASIC SCIENCE: The software systems developed within our research effort are significant not only as technical achievements in computer science, but also because these systems are based upon principled analyses of how one can best help humans cope with complex information systems. Our analyses have investigated such aspects as the role of comprehension in computer task planning [Mannes, 1989], how humans organize large amounts of information [Fischer, Stevens, 1990], and the knowledge required for locating and explaining software components in an information store [Fischer, Henninger, Redmiles, 1990]. These systems serve as platforms from which an investigation of how a cooperative arrangement between humans and computer systems can help people cope with complex information systems.

POTENTIAL APPLICATIONS: Some of the most pressing problems in an information rich society (where the resource in short demand is not information, but rather human time and willingness to attend

92

to and relevant information) are addressed by our research efforts:
(1) increasing the usability of high functionality systems (without
decreasing their usefulness); (2) support for reuse and redesign;
(3) assisting users in finding the relevant information in complex,
poorly structured information stores; (4) providing assistance in
creating the structure necessary to achieve reuse and redesign
capabilities; (5) decreasing the information overload problem and
(6) supporting new learning strategies such as learning on demand.

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(N): Human Performance and Naturalistic Decision Dynamics
(O): Acquisition, Maintenance and Transfer of Skills

CONSEQUENCES OF INDIVIDUAL DIFFERENCES IN BRAIN ORGANIZATION FOR HUMAN PERFORMANCE

MDA 903-86-K-0320   8/86 - 7/90
Georgia Institute of Technology   Joanne Green
                                                         Dennis J. Folds

SCIENTIFIC OBJECTIVES: Specific objectives are (1) to investigate various methods of inferring brain organization, (2) to examine relationships among measures of brain organization and human performance on a variety of tasks, and (3) to infer how knowledge of brain organization can be applied to improve system design and/or training.

APPROACH: The approach is to conduct studies in which various measures of brain organization and performance data are collected from volunteer subjects and analyzed from both experimental and correlational perspectives. Candidate measures of brain organization include gross dominance measures (e.g., handedness, footedness), certain fine performance scores (e.g., finger-tapping speed asymmetry), and electrophysiological measures of brain activity (e.g., power in the alpha band of the EEG, amplitude of the P300). The initial studies examine relationships among these measures and performance of simple laboratory tasks. Subsequent studies extend to high-workload, multiple-task laboratory environments and finally to tasks associated with a selected application area.

PROGRESS: In the first year, relationships among the candidate measures of brain organization were assessed, using simple laboratory tasks. Prominent among the results was the finding that the mean and variance of P300 amplitude appear to vary as a function of brain hemisphere and handedness. In the second (current) year, relationships between behavioral indicators of brain organization and performance in a dual-task environment were examined. The effects of demand for rapid visuospatial processing (manipulated by presence/absence of redundant auditory information) is of particular interest.

CONTRIBUTIONS TO BASIC SCIENCE: This effort will enhance understanding of relationships among gross behavioral, fine behavioral, and electrophysiological measures of brain organization, and how these various measures co-vary with performance on a variety of tasks.

POTENTIAL APPLICATIONS: Implications for applied problems are apparent in two areas. First, inference of workload from electrophysiological measures of brain activity must consider individual differences in brain organization and the associated differences in the mean and variability of the measures in baseline (low workload) conditions. Second, differences in ability to

process visuospatial information from multiple sources may be compensated for by provision of redundant auditory information. High-workload environments and sterile auditory environments (e.g., remotely-operated vehicles) are considered prime candidates for applications of results to Army problems.

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(N): Human Performance and Naturalistic Decision Dynamics
(O): Decision Making and Problem Solving

AN INVESTIGATION OF THE EFFECTS OF STRESS ON JUDGMENT AND DECISION MAKING IN DYNAMIC TASKS

MDA 903-86-C-0142   9/86-10/90
University of Colorado   Kenneth Hammond

SCIENTIFIC OBJECTIVES: The chief goals of our research are: (1) to increase understanding of judgement and decision making under uncertainty in changing task conditions, and (2) to evaluate the effect of stress on such judgments and decisions.

APPROACH: Our approach made use of "representative design," that is, studying experts under conditions representative of their work. First, we first studied experts (research meteorologists) making specific forecasts (hail and microbursts) under highly controlled static task conditions in order to discover whether the results obtained under these widely employed research conditions would generalize to dynamic task conditions (i.e., in which information is changing over time). Second, we studied experts under controlled conditions in dynamic task circumstances representative of actual forecasting work in order to test that generalization and to learn about judgment and decision making under conditions where information changes over time (specifically, forecasting the microburst). Third, we studied experts under fully representative but controlled work conditions in order to test the utility of concepts derived from the development of a theory of judgment and decision making in dynamic tasks (Hammond, 1988). Fourth, we undertook field studies of forecasters in operational conditions under high and low stress. Fifth, we reviewed thoroughly the literature related to the above work and prepared two annotated bibliographies.

RESULTS AND CONCLUSIONS: Four of the five steps were completed, reports were written, and manuscripts submitted for publication. Data were collected for the third step and are now being analyzed. Principal findings are:

1. Fundamental concepts developed over the past two decades in relation to judgment and decision making behavior in static tasks did in fact generalize, that is, were found to be useful descriptions of behavior in dynamic tasks, thus providing encouraging evidence for the development of a cumulative science (see Stewart, Moninger, Grassia, Brady, & Merrem, 1989; Lusk, Hammond, in press).

2. Striking individual differences (disagreement in judgments) were found among experts in the dynamic task (forecasting the microburst) despite the fact that the experts had worked for several years and believed (incorrectly) that they were in close agreement, thus demonstrating once more (a) the risk of "false agreement" found in previous research on static tasks, and

99

(b) the risk entailed in building an expert system on the information provided by a single expert (Lusk & Hammond, in press).

3.   The field study provided clear evidence that the forecasters performed better (made more accurate forecasts) under stressful than nonstressful conditions, thus demonstrating that conventional wisdom (that performance deteriorates under stress) cannot be relied upon (see Lusk, Mross, and Hammond, 1989).

4.   The results of reviewing the literature on stress and decision making were clear: There is no set of established principles that can be used to predict judgment and decision making behavior under stress.

CONTRIBUTIONS BASIC SCIENCE: 1.   Discovery of the generalization of descriptions of judgment and decision behavior from static to dynamic task conditions is of fundamental importance to a cumulative basic science.

2. Discovery of "false agreement" among the experts studied here is of particular significance because of the long term association of the experts. This result contributes to the work on experts' awareness (or lack) of their cognitive processes.

3.   Discovery of improved performance under stress in a representative field situation should lead to more sophisticated research approached to this topic and fewer unsupported generalizations.

POTENTIAL APPLICATIONS: All of the above basic science results carry implications for application because the work was carried out in circumstances representative of actual work conditions, an essential element of our research approach.

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(N): Human Performance and Naturalistic Decision Dynamics
(O): Decision Making and Problem solving

RECOGNITION-PRIMED DECISION STRATEGIES

MDA 903-89-C-0032   12/88 -11/91
Klein Associates, Inc.   Gary Klein

SCIENTIFIC OBJECTIVES: 1)   Evaluate the relative strengths and
weaknesses of RPD strategies; i.e., how decisions are made in
environments characterized by time-pressure, high risk and
ambiguous or incomplete information.   We are interested in
exploring the boundary conditions that call for recognitional vs.
analytic approaches as most appropriate.   2)   Increase
understanding of situation assessment; i.e., develop a conceptual
approach and methods of study that would allow us to expand current
understanding of situation assessment processes and how they might
be supported or improved in command-and-control environments.   3)
Explore implications of the RPD model for improving decision
quality; i.e., learn whether it is possible to train people to make
better use of their mental simulation abilities and to formulate
and communicate better situation assessments.

APPROACH: Conduct a literature review in the area of situation
assessment, and a multi-dimensional scaling experiment of expert
and novice firefighters.   This experiment is one of the first to
use situations as stimuli, rather than simple cues such as words.
For a research project on Commander's Intent, we have hypothesized
that intent statements in terms of actions to be performed will be
easier to follow but will be unadaptive to changing dynamics;
whereas, intent statements in terms of objectives would allow more
effective improvisation to meet changes in the situation.   The
second study is an examination of errors. We will also collect and
analyze examples of mental simulation used in decision making.

PROGRESS: Results of the experiment suggested that experienced
fireground commanders do not have static schemata for firefighting
situations; there was low consistency between ratings made during
different sessions.   In addition, the importance ratings for
concepts were influenced by the goal context. We have had the
opportunity to study errors in team decision making in a number of
contexts, and we are using these data to develop a taxonomy of team
decision errors.   We also performed a new task--a workshop on
naturalistic decision making was held in Dayton, Ohio, September
25-27, 1989.   Approximately 25 professionals working in the area
of naturalistic decision making met to discuss new models and
paradigms, and to identify directions for future research. It is
anticipated that a book written by workshop participants will be
completed by June 1990.

POTENTIAL APPLICATIONS: The findings on team decision errors and on the communication of intent will have direct implications for Army training exercises. The study of mental simulation will have implications for training soldiers to anticipate the consequences of courses of action, and for designing decision support systems that improve the ability to envision future events.

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(N): Human Performance and Naturalistic Decision Dynamics
(O): Behavioral Foundations of Systems Design

PREDICTING PERFORMANCE BREAKDOWN IN PILOTS THROUGH OBJECTIVE MEASURES OF STRESS SENSITIVITY

DAJA 45-88-C-0024   10/88 - 10/90
University of Reading   Frank McKenna

SCIENTIFIC OBJECTIVES: It is well known that stress can have an adverse effect on performance and that there are wide individual differences in response to stress. The present research aims to develop a computerized measure of stress resistance which will 1) allow the assessment of those most susceptible to stress and 2) provide a laboratory model to investigate techniques to reduce the adverse effects of stress on performance.

APPROACH: Previous research aimed at developing a measure of stress resistance has rested heavily on subjective measures. The present approach aims to develop an objective performance-based measure. To this end, a paradigm has been developed in which the effects of task irrelevant emotional stimuli are assessed.

PROGRESS: A series of studies now indicates that the paradigm has considerable potential both as a measure of stress resistance and as a laboratory model of the effects of stress on performance. In particular, it has been shown that: 1) emotional stimuli disrupt performance; 2) the disruption is exacerbated by time pressure; 3) repetition of. the emotional stimuli eliminates the disruptive effect; 4) the test is sensitive to the specific fears which people have; and 5) emotional stimuli are readily retrieved from memory. These results parallel the effects of exposure to threat in everyday life.

CONTRIBUTIONS TO BASIC SCIENCE: A great deal of previous work in this general area has greatly benefitted from animal models. For example, the influential Yerkes-Dodson Law outlining the relationship between stress and performance was based on experiments on mice. The present research seeks to develop a human experimental model to aid in determining the relationship between stress and performance and in devising techniques to reduce the adverse effects of stress.

POTENTIAL APPLICATIONS: There are two potential long-term applications of the present research. The first is the development of an objective measure of stress resistance which could be used for selection. The second lies in the development of techniques devised to reduce the adverse effects of stress. These techniques could be introduced into training programs and result in individuals being more effectively prepared for high stress situations.

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(N): Human Performance and Naturalistic Decision Dynamics
(O): Acquisition, Maintenance and Transfer of Skills

SKILLED USE OF COMPUTER SOFTWARE: IMPLICATIONS FOR TRAINING AND DESIGN

SCIENTIFIC OBJECTIVES: Our goals are to extend current theories of the acquisition and execution of routine cognitive skills to deal with the more cognitive aspects of computer use. In particular, we are concerned with the choices people make among alternative ways of performing a task (strategy selection) and the interactions of routine skills with complex problem solving behavior. This research program has the dual goals of making basic contributions to our understanding of cognitive skills and applying these results to the design of complex software systems to increase user productivity and reduce t.aining costs.

APPROACH: Our approach assumes that a given task can be hierarchically decomposed into a set of relatively elementary mental operations. These operations include retrieving items from memory, carrying out various transformations on information held in working memory, or more complex calculations assessing perceived effort. We model the task, identifying the component processes and their particular features (e.g., time course, capacity of storage, etc.), and then empirically test predictions. We look for large deviation between the predictions from this theory of routine skill and user's performance. We then extend the theory to account for these newly identified processsess. This work will be important both for its contribution to theories of cognitive skills and its application to the design of software and training materials.

PROGRESS: Our work this year focuses on three common task areas within human-computer interaction: 1) the way people navigate around complex data structures like text or a spreadsheet, 2) selection of commands using menus of various designs, and 3) entering of complex relationships into software such as formulas for spreadsheets.

We have completed a review of the modeling approach we are using, collecting converging performance parameters from various tasks and laboratories, and outlining the approach's strengths and limits.

We followed with a study aimed at understanding the development of the cognitive skills associated with learning to use software. We tracked 34 MBA students through their initial introduction to spreadsheet software through two years of use. As expected, for those students who mastered the software (completed all the tasks we asked them to in the last session), their progress was marked with shorter times and fewer errors. . Using our analysis of

component processes, we determined that the skill was centered in the retreival components of performance, not the motor skill components. Furthermore, the more frequently used tasks improved faster. However, we were surprised at both how many students had not learned to do relatively straight forward tasks even after two years of use, and how many used inefficient methods if they did succeed. Many aspects of a popular piece of software were never acquired. Productivity (performance) was far less than expected.

Two experiments are currently underway, following on to investigate learning, retention and choice of methods in software. In one, novice users of spreadsheet are taught one, two or four methods to carry out the same general task. We assess the time to learn similar methods, and the subsequent cost in performance from having to make a choice among the methods. We are also surveying among expert users how many of the available methods they know and use. In a third study, we are assessing the performance costs in experts of knowing a variety of methods, examining the processes of choice and the factors that influence it. We look at both the time to choose and the actual choice over a variety of situations with very different parameters. We are modeling the process we believe to be operative, a mixture of memory retrieval and choice.

Two additional experiments extend our model of skill performance. One studies the selection of command items in menus of various physical layouts and operative styles. Another assesses the cognitive load from entering complex relationships in software, such as formulas for spreadsheets and nested expressions in programming languages such as LISP.

CONTRIBUTIONS TO BASIC SCIENCE: We are extending theories of the acquisition and execution of routine cognitive skills to deal with more cognitive aspects such as choices of alternative methods of performing a task and the interactions of routine skills with complex problem solving behavior.

POTENTIAL APPLICATIONS: Many functions in the military require the use of powerful and complex computer software running on increasingly sophisticated computer systems. However, the productivity gains and cost savings that were promised by developers are rarely achieved because training costs are high and because personnel rarely completely master these complex systems. One goal of this project is the derivation of principles of design and training based on the application of sound cognitive theory. These design principles will provide developers with the knowledge necessary to build highly functional systems, better matched to the task and user's capabilities, and more effective training methods.

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(N): Human Performance and Naturalistic Decision Dynamics
(O): Aquisition, Maintenance and Transfer of Skills

STIMULATION AND TRAINING FOR STRESS ENVIRONMENTS: A META-ANALYTIC AND EXPERIMENTAL EVALUATION

New Start
Florida Maxima Corporation James E. Driskell
Brian Mullen

SCIENTIFIC OBJECTIVES: This project has three goals: (1) quantitative research integration using the methods of meta-analysis of the literature on stress and training; (2) identification from this meta-analysis of the most effective approaches for reducing the effects of stress on task performance; and (3) primary experimental research to evaluate the effectiveness of selected appraches on actual training groups.

APPROACH: The authors will build on their prior research which found that overlearning is an effective means of enhancing retention. Effects of other training manipulations on task performance will be investigated including effects of training fidelity, confidence, phased training, indoctrination, preparatory information, modelling, coping skill training, and cohesiveness.

(N): Human Performance and Naturalistic Decision Dynamics
(O): Aquisition, Maintenance and Transfer of Skills

PERSONALITY, MOTIVATION AND COGNITIVE PERFORMANCE

New Start

Northwestern University
William Revelle
Kristen Anderson

SCIENTIFIC OBJECTIVES: This project represents a continuing investigation of performance based on a theory of a unitary motivational state (arousal) and its interaction with personality (e.g., impulsiveness) and situational (e.g., time-of-day) variables.

APPROACH: A prototypical experiment invoves crossing one or two personality variables with one or two situational variables and one or two task variables. Experiments will be designed so that the effects interest are found in disordinal two, three and four-way interactions and quantitative predictions rather than simple main effects. This research sets the stage for examining the interactive effects of personality, cognitive demands, and presence of stressors for such military activities as personnel selection and operations management.

(N): Human Performance and Naturalistic Decision Dynamics
(O): Behavioral Foundations of Systems Design

ASSESING THE EFFECTS OF SYSTEM FAILURE, TIME LIMITATIONS, AND OPERATOR COSTS ON DECISION-MAKING STRATEGIES

New Start
Central State   B. Walker

SCIENTIFIC OBJECTIVES: This project seeks to determine how the human operator deals with the possibility of system failure when reliability of the data supplied are uncertain.

APPROACH: Initial experiments will examine operators' decision making strategies in a variety of situations where decisions must be based on possibly faulty data. Later experiments will examine the interactions of system failure, environmental demands and operator decision making.
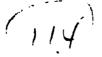
Learning, Cognition, and Problem Solving

Future conflicts involving the United States may range from short, high intensity conflicts, to protracted low intensity conflicts. Soldiers must be trained for such conflicts using high technology on a distributed battlefield. Soldiers and Officers will have to reason flexibly and to solve problems in a creative manner, often with little guidance from precedent or doctrine.

Army training systems must prepare soldiers with knowledge and skill which is retained over periods of time, which is flexible enough to serve in the real world under a variety of demanding battlefield conditions.

The goal of our program of research in learning, cognition, and problem solving is to develop a scientific base for the design of Army training systems. Because many of the issues that arise are not part of the existing technological base in applied training and instructional development, it is necessary to develop a core of scientific knowledge to address the many issues that are raised by new training needs.

(N): Learning, Cognition and Problem Solving
(O): Acquisition, Maintenance and Transfer of Skills

RESEARCH TOWARDS A GENERAL SKILL OF COMPUTER PROGRAMMING

Completed

MDA 903-85-K-0343
7/85-7/89
Carnegie-Mellon University
John Anderson

SCIENTIFIC OBJECTIVES: The goal of this research is to develop a theory of skill acquisition in general and how acquisition of one skill transfers to another skill. In addition, we want to incorporation this understanding into general intelligent tutoring architecture for teaching programming languages.

APPROACH: We are studying the acquisition and transfer of programming skills across languages and across uses. We are looking at transfer among the activities of coding, debugging, and program simulation. Computer simulation models of these mental activities are being developed. The architecture for these simulation models is being used as the core of a general architecture for teaching computer programming.

RESULTS AND CONCLUSIONS: We have developed a general model of debugging and of program evaluation and related it to an existing model of code generation. In addition, we have developed a general theory of the transfer of cognitive skills. A series of experiments have confirmed the predictions of this theory when applied to evaluation, coding, and debugging. The first experiments have been done studying the transfer across programming languages. Finally, a basic tutoring architecture has been set in place.

CONTRIBUTIONS TO BASIC SCIENCE: This research has made direct contributions to a theory of human learning and transfer. It is hoped that the research on transfer across programming languages will also make contributions to a theory of the role of planning in human problem solving.

POTENTIAL APPLICATIONS: The tutoring architecture will be capable of teaching computer programming. It is a first step towards developing a general authoring system for intelligent tutoring.

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(N): Learning, Cognition and Problem Solving
(O): Aquisition, Maintenance and Transfer of Skills

TASK DECOMPOSITION AND SPECIFIC SKILL TRAINING AS TOOLS IN THE IMPROVEMENT OF THE COST EFFECTIVENESS OF SIMULATOR-BASED TRAINING

Completed

MDA 903-86-C-0346   10/86 - 10/89
University of Illinois at Urbana-Champaign   Emanuel Donchin

SCIENTIFIC OBJECTIVES: To elucidate principles for the design of part-task training regimes for complex tasks. This project compares strategies of part-task training within the context of different approaches to task analysis.

APPROACH: The target task is a computer-controlled game called "Space Fortress", which was designed to permit manipulation of the demands it places upon the subjects' acquisition of complex perceptual, motor and strategic skills. Two part-task training regimes that differed in their structuring of practice on the sub-tasks were compared with each other and with a "whole task" training regime on acquisition of the complex skill: (1) an integrated approach, in which the subject was always confronted with the full task (however, part-tasks were created by directing the subject's attention to components of the task through modified scoring and augmented feedback which emphasized special skills); and (2) a hierarchical approach, which derived the optimal strategy for success in the game and then designed a series of sub-tasks that trained the subjects in this strategy. The project also includes measures of the degree to which resulting task performance is resistant to disruption by secondary tasks. The battery of tasks can also serve as a method of task analysis, whose utility is also being evaluated in this project.

We are also testing an approach to task analysis that uses Three-Mode Factor Analysis to develop a descriptive framework for simplifying (i.e., reducing the dimensionality) of the complex database consisting of multiple measures of task performance obtained over numerous sessions.

RESULTS AND CONCLUSIONS: Experiments comparing the various training conditions found that both part-task training methods were superior to the whole-task method. However, the hierarchical approach led to highest scores and the greatest efficiency in dealing with elements of the game. On the other hand, subjects in the integrated group were most resistant to the interference of concurrent tasks. These data demonstrate the importance of including not only measures of rate of learning and final performance, but also measures of resistance to interference that these regimes foster in the evaluation of training methods.

The Three-Mode Factor Analysis procedure was applied to the database acquired in an earlier project, in which a large number of subjects were run. We compared the performance of two control groups, trained on the whole task in two different labs (University

of Illinois and the Technion, in Israel). While the learning curves of the Israeli and American subjects were parallel, the Israeli group displayed consistently poorer performance. The Three-Mode Factor Analysis yielded a simple description of the data, and indicated that the Israeli subjects were more frequently associated with inefficient strategies.

CONTRIBUTIONS TO BASIC SCIENCE: Our contribution to experimental psychology lies in the possibility of extending and refining models of working-memory such as that proposed by Baddeley (1986), through the use of the dual-task methodology. Our contribution to engineering psychology consists in clarifying the rules that determine an effective design and selection of part-task training drills.

POTENTIAL APPLICATIONS: This research has potential bearing on the design of training programs devoted to teaching complex perceptual, motor and strategic skills, such as those involved in a variety of complex military systems. It has the potential for improving the quality of training, and of reducing the cost, time and effort involved. This effort also relates to the design of simulators and to the issue of fidelity in simulator design. It would seem that it is far more important to focus on the training of specific skill components and well designed strategic approaches than to create a faithful replica of the "real" world.

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(N): Learning, Cognition, and Problem Solving
(O): Aquisition, Maintenance and Transfer of Skills

COMPARATIVE EVALUATION OF KNOWLEDGE ASSESSMENT PROCEDURES

Completed

MDA 903-87-K-0002   12/86 - 11/89
New York University   Jean-Claude Falmagne

SCIENTIFIC OBJECTIVES: The objective is to design, test and implement computerized knowledge assessment procedures, capable of competing successfully with a human expert examining a student. The basic principles governing these procedures should be applicable to widely different fields. A primary focus of the research is a systematic comparison between the assessment performances of human experts and computer programs.

APPROACH: Our exemplary field of application is elementary mathematics at the high school level. This research has four phases: (1) organization of the possible knowledges states into a convenient and economical mathematical structure (called the knowledge space); (2) test and refinement of this structure on extensive empirical data; (3) elaboration and calibration of the knowledge assessment algorithms on the basis of the experimental data collected; (4) comparative analysis of the performance, for the same students, of calibrated knowledge assessment algorithms and of human examiners.

RESULTS AND CONCLUSIONS: In Phase 1, we have developed the mathematical theory and the related computer algorithms, permitting the efficient query of human experts and construction of the knowledge space as conceived by the expert. This program has been tested on a few experts, and appears to be very efficient. (See Koppen & Doignon.) The statistical methodology required for Phase 2 has been developed by Falmagne, and is presented in his paper in press in Psychometrika. The algorithms to be used in Phase 3 and 4 have been developed by Falmagne and Doignon. A large scale application of these techniques is in progress.

CONTRIBUTION TO BASIC SCIENCE: This work represents a sharp departure from traditional approaches to psychometric testing, which typically use numerical models based on the concept of skills or abilities. Until very recently, numerical models were essential since they were the only models capable of being analyzed in any depth, for which detailed predictions could actually be worked out. Simplicity could have been operationally defined by the fact that the analysis of the model could be performed with a desk calculator, or a first generation computer.

With the coming of age of much more powerful computers, the type of models entertained by scientists and the concept of simplicity itself are changing. As a consequence, more realistic models, combinatorial in character, may be entertained.

117

More generally, an essential part of this work consists in the development of a fundamental theory of the organization of knowledge, from the view point of the possible states of individuals in a specified population.

POTENTIAL APPLICATIONS: Accurate and efficient assessment of an individual's state of knowledge concerning a body of information. Since the algorithms developed in our research are very general, potential applications may extend to apparently very different fields, such as medical diagnosis, pattern recognition or failure analysis (of a complex mechanical or electronic device).

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(N): Learning, Cognition and Problem Solving
(O): Acquisition, Maintenance and Transfer of Skills

QUALITATIVE MODELS FOR COMPUTER-BASED INSTRUCTION

SCIENTIFIC OBJECTIVES: The object is to advance theoretical work on the design and use of qualitative models for instructional purposes. In that context, we are investigating how experts use and coordinate multiple models (electrical and functional) when troubleshooting. The results of the empirical studies and theoretical work contribute to theories underlying the design of intelligent tutoring systems.

APPROACH: We are formulating behavioral, functional and physical models for reasoning about electrical circuits. These alternative conceptual models are forming the basis for an intelligent tutoring system that is capable of helping students to acquire some subset of these models. We are going to conduct research to determine the effect of teaching multiple models, as opposed to a single model, on students' problem solving capabilities. We are also studying the use of both text and diagrammatic explanation in fostering understanding within the instructional system.

RESULTS AND CONCLUSIONS: We have implemented within the tutoring system a progression of models (and their accompanying problem sets) that reason qualitatively about the behavior of electrical circuits. We are continuing our theoretical work on the design of alternative models (functional and physical) that can explain and reason about circuit behavior from different perspectives. We have also conducted an experiment that uses a reaction-time methodology to investigate the nature of the mental models that students use when reasoning about the behavior of simple electrical circuits.

CONTRIBUTIONS TO BASIC SCIENCE: From a cognitive science perspective, this research will contribute to theories of the nature of understanding, the evolution of expertise and its application to problem solving contexts. From an instructional science perspective, it will contribute to theories of learning and motivation, the generation of explanations, the creation of problem sets to foster learning and the role of alternative cognitive representations and models. From a computer science perspective, it will contribute to theories concerning the architecture of intelligent learning environments and the design of instructional tools.

POTENTIAL APPLICATIONS: Educational tools: We are developing an intelligent, computer-based learning environment for teaching basic

electricity and electrical troubleshooting. Curriculum materials:
As part of this project, we will develop experimental materials for
teaching students about electricity and electrical circuits. These
materials could be used as the foundation for a course in basic
electronics and electrical troubleshooting. Furthermore, in the
process of creating the intelligent, computer-based, learning
environment, we will specify precisely the mental models that
students are to acquire. We will also generate problem sets
appropriate for helping students to induce a particular model
transformation. These problems sets, and the associated
explanations generated by the models, could be used by instructors
who want to teach qualitative reasoning, but who are not able to
give their students access to the instructional system. Assessment
tools: The problem sets will also be valuable in assessing both
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(N): Learning, Cognition and Problem Solving
(O): Acquisition, Maintenance and Transfer of Skills

OPTIMIZING THE LONG-TERM RETENTION OF SKILLS: STRUCTURAL AND ANALYTIC APPROACHES TO SKILL MAINTENANCE

SCIENTIFIC OBJECTIVES: To identify the characteristics of knowledge and skill which are most resistant to decay due to disuse. To elucidate principles which will specify those aspects of a complex skill that resist decay over periods of disuse and how they are distinguishable from more fragile components.

APPROACH: The research program can be divided into two complementary parts. The first part is concerned with describing the structure of existing skills. Existing methods will be refined and adapted to allow examination of skill components and assessment of their retention characterisrics during long periods of disuse. The second part is concerned with experimental analysis of factors influencing and inproving retention of skill components. This methodology will be used to check a set of hypotheses concerning the characteristics that distinguish between permanent and nonpermanent components of knowledge and skill. A new line of investigation, involving both analytic and structural approaches, began consequent to the arrival of three Army tank simulators. This effort is concerned with the study of a complex military skill.

RESULTS AND CONCLUSIONS: For the analytical approach, five laboratory analogues of component skills of electronics technicians were investigated. The laboratory tasks involve (a) target detection, (b) data entry, (c) learning logical rules involved in computing circuit design, (d) memory for numerical calculations, and (e) temporal, spatial and item components of memory for lists. Further, four natural skills learned by the college population during their prior education were studied to assess what aspects of these skills are retained over long periods of time. The natural skills include (a) mental multiplication, (b) algebra, (c) data entry, and (d) temporal, spatial and item components of memory for schedules. We have found almost perfect retention of the target detection, data entry and mental multiplication skills. In contrast, we have found rapid forgetting of episodic temporal, spatial and item information and more forgetting of specific algebra rules than of general algebraic procedures. These findings indicate that knowledge, or content, is more susceptible to forgetting than procedures, or skills. We have proposed a theoretical framework in which to interpret our findings. According to this proposal, memory representations cannot be divorced from the procedures which were used to acquire them, and the durability of memory depends critically on the extent to which

these learning procedures are reinstated at test. We have recently initiated three studies to provide more direct support for this theoretical framework. These studies involve the domains of arithmetic calculation, Morse Code reception and foreign vocabulary learning.

For the structural approach, we have focused our research efforts on the examination of the detailed structure of cognitive processes at the time of acquisition of knowledge such as foreign vocabulary items, as well as at the time of the retrieval of that knowledge at delayed retention tests. Our results show that a large proportion of the originally acquired foreign vocabulary items cannot be retrieved after a month and only a small proportion can be retrieves after a year. A more detailed examination of the memory encodings of the foreign vocabulary items shows that some aspects of these encoding (e.g., the mediating keywords) are retained well even after a year. An analysis of the retrospective verbal reports on successful retrievals at delay shows that the retrieval is virtually always mediated by the same cognitive structures originally accessed to encode the vocabulary item at study. We are currently examining whether memory encodings capitalizing on stable associations in semantic memoty are closely related to enhanced long-term retention and to what extent the frequency of such encodings can be increased by instructional procedures.

CONTRIBUTIONS TO BASIC SCIENCE: The investigation of human learning and memory has been a topic of basic scientific research for many years. However, investigators have typically focused on retention over relatively short time intervals and retention of knowledge, or content, rather than of procedures, or skills. The present work extends this line of investigation by examining longer delay intervals and different types of skills. It is evident from our findings that these new considerations are essential, and that the conclusions from earlier studies must be qualified.

POTENTIAL APPLICATIONS: The overriding practical question of this research is how to ensure, through training, that a skilled worker (such as an electronics technician, a tank gunner or a code recipient), has a behavioral tool kit which is just as or nearly as permanently functionable as his or her hardware kit. The eventual goal is to be able to make relevent recommendations about training routines for long-term skill maintenance.

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Bourne, L.E., Jr. (1988). <u>Explicit and implicit aspects of motoric priming.</u> Invited address. Centennial celebration, Department of Psychology, University of Wisconsin (September).

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Ericsson, K.A. (1987). The nature of exceptional performance. Invited colloquium in the series "Kolloquien Allgemein Pschologie und Pschophysologie," Freie Universitaet, West Berlin (December).

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Ericsson, K.A. (1988). <u>Peak performance and age: An examination of peak performance in sports</u>. Invited talk at European Science Foundation conference on longitudinal research and the study of successful (optimal) aging, Castle Ringberg, Tegernesse, West-Germany (June).

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(N): Learning, Cognition and Problem Solving
(O): Decision Making and Problem Solving

A COGNITIVE ARCHITECTURE FOR SOLVING ILL-DEFINED PROBLEMS

Completed
MDA 903-86-K-0297   9/86 - 9/89
UCLA   Keith J. Holyoak
Princeton University   Paul Thagard

SCIENTIFIC OBJECTIVES: The object was to develop a psychologically realistic model of human problem solving that will be able to deal with ill-defined problems (i.e., problems for which the initial goal or the set of allowable operators is inadequate for developing a solution). Psychological evidence has indicated that human problem solving and decision making are often guided by anlogies between the current situation and past cases. The role of analogies is particularly important in military problem solving and decision-making tasks, in which task-appropriate actions must be generated under conditions of uncertainty and time pressure, and instructional time is limited. Analogies are often used in instructional settings to provide initial understanding of a new domain. At the same time, people sometimes fail to make use of potentially valuable analogies from other domains unless a teacher provides direct guidance. The project aimed to find ways to automate important aspects of analogy use, as well as to identify new training methods that can improve human retrieval of relevant cases in problem-solving contexts.

APPROACH: The approach was to integrate experimental data on human analogical reasoning and problem solving with the development of computer simulations capable of performing similar tasks.

RESULTS AND CONCLUSIONS: A computational model of analogical mapping (ACME) was constructed, which uses connectionist, parallel-processing techniques to find optimal sets of correspondences between descriptions of complex situations (e.g., problems, scenarios, or choice possibilities). A small number of basic contraints on mapping derived from experiments on human use of analogies provided the core of the mapping model. This model was used to simulate a number of experimental results obtained in psychological studies. In addition, a related model of the retrieval of analogies from memory (ARCS) was also developed, as was a model of the process by which competing explanations can be evaluated by assessing explanatory coherence (ECHO). Experimental work included a series of experiments in which subjects received a number of initial cases illustrating procedures for solving a class of problems. After varying delays, ranging up to a week, subjects were tested on their ability to apply spontaneously the learned procedures to superficially different problems. The number of initial examples, and the extent to which training focused on goal-relevant aspects of the examples, were the major factors varied. The results indicated that exposure to multiple examples, coupled with experience in applying the examples to a problem, can

produce transfer after a substantial delay.

CONTRIBUTIONS TO BASIC SCIENCE: The computational models of retrieval and mapping of analogies succeeded in modeling a number of major phenomena related to analogical problem solving. The models proved sensitive to surface and structural similarity between situations in ways comparable to human analogical reasoning. In addition, the models of retrieval were applied successfully to relatively large and complex data bases and were able to provide efficient access to the most relevant cases even when they were embedded among numerous competing cases of lesser relevance. The experimental studies demonstrated that goal-directed training, using at least three initial examples, significantly increased spontaneous analogical transfer in a problem-solving task presented a week later.

POTENTIAL APPLICATIONS: The computational models developed in the project may provide the theoretical foundation for computer-based aids for problem-solving and decision-making tasks. It may be possible to construct a computational device that uses analog retrieval and mapping to assist a human problem solver. There is clear potential for use of such systems by Army personnel to enhance their performance. In addition, the research may help design more effective training procedures, both by providing criteria for selection and development of instructional analogies, and refining initial learning tasks so as to increase subsequent retrieval and use of the procedures being taught.

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(N): Learning, Cognition, and Problem solving
(O): Acquisition, Maintenance, and Transfer of Skills

SEMI-AUTOMATIC METHODS FOR KNOWLEDGE ENHANCEMENT

Completed
DAJA 45-86-C-047   9/86 - 12/88
Turing Institute   Donald Michie

SCIENTIFIC OBJECTIVES: The object is to automate the synthesis
and refinement of new knowledge which is beyond the grasp of the
unaided human intellect, because of a domain's "ultracomplexity."
Using chess-experts as laboratory models, we are addressing the
following issues: (1) how to automate the development of
concepts from expert-supplied examples; (2) how to automate the
validation of machine-generated comprehensive factual databases
about a given domain; (3) how to automate the development of
summarizing concepts from comprehensive databases of raw facts;
(4) how to achieve (3) for problem domains so complex that no
effective human concepts exist or can be constructed by expert
brains; (5) how to derive from (4) a means of imparting the newly
developed concepts to human experts as a basis of mental mastery
of what previously they found impenetrable.

APPROACH: The approach is to select endgames agreed to be beyond
human mastery and then to build exhaustive databases of these
selected endgames. Each database contains a complete model of
the problem space. In parallel, we study (1) how the unaided
human expert tackles the problem, and how far he can be aided by
use of the database itself, and (2) the design and implementation
of software tools to structure automatically the mass of
information contained in the databases in ways that can then be
understood and assimilated by the human expert. The tools are
applied not only to the endgame databases, but also to realworld
problems.

PROGRESS: In the four years of our investigation we have
achieved the following: (1) A method of using inductive
algorithms as training tools, by providing a (software) pupil to
instruct rather than a text to read. This produced better
performance than the conventional drill-and-practice methods.
(2) Algorithms which automatically structure a large problem
space into "concepts" which are understandable to the human
expert. Results have been positive in the automatic structuring
of a chess endgame and to test the generality of the method in
parity and taxonomy problems. Finally in a real-life problem of
clinical neuropsychology, the algorithms produced a system
automatically where results agreed with the clinical expert in 90
percent of the cases. This compared favorably with a 63 percent
agreement produced by an expert system built by the expert
himself. (3) The algorithms have been proved to be complete and
correct. Work is continuing on the building of databases for yet
more complex end games.

CONTRIBUTIONS TO BASIC SCIENCE: The proof of completeness and correctness for the structuring algorithms constitute a basic scientific contribution. In addition, the work on database construction has produced new chess knowledge.

POTENTIAL APPLICATIONS: This work provides an approach to machine problem solving in real-world domains whose complexity puts them beyond the unaided human grasp. Such domains include routing, placement, multi-channel signal interpretation and multi-variable process control. In addition, there are indications that these new software tools will have significant teaching possibilities.

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(N): Learning, Cognition and Problem Solving
(O): Behavioral Foundations of Systems Design

NATURAL LANGUAGE ACCESS TO INTELLIGENT SYSTEMS

Completed
MDA 903-86-K-0242   7/86 - 6/89
Princeton University   George A. Miller

SCIENTIFIC OBJECTIVES: Work under this contract had two components, both aimed at facilitating natural language access to intelligent systems. One aspect was concerned with increasing the vocabularies of personnel who use intelligent systems, the other was an attempt (jointly supported by ONR Contract N00014-86-K-0492) to increase the vocabulary that computer systems can process intelligently.

APPROACH: A dual approach was followed. (1) To determine conditions that facilitate user's vocabulary growth, psychological experiments were conducted to determine how the context of a word constrains its meaning, how context contributes to learning new words, and how those contributions can be optimized in a tutoring system. (2) To create a lexical database incorporating semantic relations between works and to make that database available to workers in computational linguistics who are working toward language comprehension by computer.

RESULTS AND CONCLUSIONS: Under the conditions of the experiments on the effects of context, it was found that *dictionary definitions* and pictures produced little word learning; the most effective help was another sentence suitable to the same text and using the target word in the same sense, which challenged learners to think and to form connections between the word and what they already knew. Pictures were not effective in teaching abstract words. Combining different kinds of help was not effective--learners chose the help they liked best and ignored the rest. Subsequent research focussed on linguistic contexts. A new technique was developed, "the method of sorting linguistic contexts," that permitted estimations of the discriminability of contexts. It was found that different senses of the same word are accurately discriminated by the method, confirming that context disambiguates polysemous words. And words that are related in meaning generally occur in contexts that are difficult to discriminate. Another series of studies developed a technique of lexical tutoring: learners were shown alternative sentences (not definitions) and a pause of 20 seconds was given, ending in a hint. This tactic appeared to be successful without the intervention of a coach and is presently being incorporated into a handheld teaching device that will be tested in further experiments.

The second component developed an on-line lexical database, WordNet, to be used in processing natural language by computers. The basic plan of WordNet can be visualized as a vocabulary matrix formed by N words x M meanings, where an entry in a cell means that the word in that column can be used to express the meaning in the

row of the matrix. A meaning is represented in WordNet by the set of synonyms that can be used to express it; these synonym sets (synsets) provide convenient entries between which semantic relations are represented by labelled pointers. In addition to synonymy, the database is organized by hyponymy/superordination, meronymy/holonymy, tropnymy, and entailment. There are approximately 32,000 nouns in WordNet, organized into some 25,000 synsets; they are topically organized into 25 separate lexical files. It contains well over 13,000 adjectives organized into some 10,000 synsets, and 4,500 verbs organized into 3,300 synsets. Software for the interface between a user and the lexical database, referred to as Lexpert, is also available.

CONTRIBUTIONS TO BASIC SCIENCE: This work led to a theory of the contextual correlates of meaning to guide future research on vocabulary acquisition and to relate linguistic context and semantic similarity, and to the development of experimental methods to test the theory. Also, WordNet is a tool available to computational linguists, and the principles underlying it are a contribution to our understanding of semantic memory.

POTENTIAL APPLICATIONS: The technique for getting readers to think about new words can be incorporated into lexical tutoring devices. WordNet can be used in various kinds of language processing: inferencing, information retrieval, and wordprocessing support.

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(N): Learning, Cognition, and Problem Solving
(O): Acquisition, Maintenance, and Transfer of Skills

BEHAVIORAL VARIABILITY, LEARNING PROCESSES AND CREATIVITY

	Completed
DAJA 45-85-C-0038	2/87 - 5/88
University of Liege	Marc Richelle

SCIENTIFIC OBJECTIVES: The research is aimed at investigating properties of behavioral variability in humans and at elucidating underlying processes. The first phase of the research was specifically aimed at investigating effects of cognitive factors ("mobility of thought", capacity of "abstractness", cognitive style) and environmental factors (reinforcement contingencies and visual feedback) on behavioral variability as a function of age. The second phase of the research is devoted to the study of the relation between socio-professional factors on behavioral variability in adults.

APPROACH: Subjects are exposed to a visual display presenting a 4 x 4 matrix with appropriate animation. The task is to bring a target located at the top left corner to the bottom right corner by correctly exploiting two responses with distinct effects (one step down, one step right). Additional constraints are manipulated to test the induction of variability or stereotypy and to estimate the effects of variability training on transfer. Results are compared to performances on tests adapted from Piaget and on field dependence-independence tasks.

PROGRESS: Phase One studies involved subjects ranging in age from 5 to 24 years. Findings from these studies revealed (a) greater stereotypy in the younger children's behavior, (b) more sensitivity to reinforcement contingencies in older children, and (c) no relation between behavioral variability and cognitive style or "mobility of thought." This first experiment suggests that variability is an inherent dimension of behavior, sensitive to contingencies of reinforcement. However, the capacity to vary in a correct way is limited by the subjects' general developmental level.

The second phase compared 18-22 year old who attended either a university or a technical school, and yielded the following results. For all subjects, variability training increased performance levels in a new situation, but some differences were found between the educational groups in rate of learning. No group differences were found in spontaneous variability level.

CONTRIBUTIONS TO BASIC SCIENCE: The framework of the research is provided by learning theory (especially the variation-selection concept) and cognitive developmental theory (essentially along Piaget's constructivist lines). Intra-individual variability is viewed as the necessary condition of learning as well as an essential feature of all problem solving and creative behaviors. Integrating learning and cognitive processes will provide a

POTENTIAL APPLICATIONS: It seems that while strong disciplined stereotyped habits used to be in favor, reacting in a flexible way in complex situations is now of critical importance in a military context. It is therefore crucial to understand how to train people to be more flexible. Invoking the loosely-defined notion of innate creativity does not advance practical applications. We argue, instead, that there is no antinomy between fundamental mechanisms of learning (if variability is given its rightful place) and the development of flexibility in novel situations. Such knowledge will be of major interest to those who have to train others to face the unexpected.

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(N): Learning, Cognition and Problem Solving
(O): Acquisition, Maintenance and Transfer of Skills

QUICK DEVELOPMENT MICROCOMPUTER SYSTEM: TRAINING AUTOMATIC COMPONENTS FOR ELECTRONIC TROUBLESHOOTING

Completed
MDA 903-86-C-0149   5/87 - 8/89
University of Pittsburgh   Walter Schneider

SCIENTIFIC OBJECTIVES: Our research investigates how diagnostic troubleshooting skill develops with practice. In a series of experiments, we are studying the crucial role of practice in the development of complex skills. We are particularly interested in finding training methods that can build up automatic component skills so that they can be executed reliably, with little effort, and can be incorporated into more complex skills. Efficient and inexpensive training methods are then implemented in software for micro-computers. An important aim of the research program is the development of a model of skill acquisition that integrates a wide range of findings on learning.

APPROACH: Data on the acquisition of digital troubleshooting skill were collected. A variety of different training methods were manipulated within and between groups of subjects to identify those methods that best facilitate skill acquisition. The different methods make use of different problem solving strategies and different amounts of practice on component skills. During the training period, subjects performed electronic troubleshooting tasks and the performance reliability, speed, and workload of the component skills were assessed. The subjects' performance in these experiments was then modeled with computer simulations so that the model of skill acquisition under development could be tested and extended. The modeling incorporated connectionist and production system modeling techniques.

RESULTS AND CONCLUSIONS: We have developed a set of computerized training procedures to develop combinatoric troubleshooting, and elaborated on the theory of skill acquisition. We have developed a training system (Quick Development Microcomputer software, or QDM) for a combinatoric troubleshooting system that has enabled novice, non-technically trained college students to develop substantial troubleshooting skills in 30 hours of training. The results showed rapid learning of the component tasks, excellent transfer to novel circuits and no loss of skill after six months. In contrast, there was significant decay of declarative knowledge. Moreover, we have made substantial progress in interpreting the use of workload in skill acquisition and high workload performance (Schneider & Detweiler, 1987).

We have developed a connectionist/control architecture model (CAP2) to simulate instructed learning and practice in the learning of combinatoric troubleshooting. Using the connectionist/control structure, CAP2 can use verbal rules to acquire the skill quickly and gradually develop automatic components to perform and

generalize the task under high workload.

CONTRIBUTIONS TO BASIC SCIENCE: The theoretical approach taken in our work integrates a broad range of findings on learning and skill acquisition. Strictly rule-based or strictly connectionist models fail to account for transitions in learning (such as the transition from controlled to automatic processing) that are accounted for by our connectionist/control model. The use of this model to account for the fine-grained aspects of learning in electronic troubleshooting provides a detailed analysis of learning. The modeling of high workload performance allows interpretation of the importance of multitask training in high workload environments and the interaction of working memory in learning.

POTENTIAL APPLICATIONS: Our findings suggest principles for selecting efficient and inexpensive training methods for complex skills. Efficient training methods can be devised by decomposing complex skills into component skills and providing the appropriate amounts of practice for those components.

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(N): Learning, Cognition and Problem Solving
(O): Acquisition, Maintenance and Transfer of Skills

KNOWLEDGE ACQUISITION FOR APPLICATION: COGNITIVE FLEXIBILITY AND TRANSFER OF TRAINING IN ILL-STRUCTURED DOMAINS

SCIENTIFIC OBJECTIVES: The general purpose of this program of research is to determine how knowledge should be acquired and organized to facilitate a wide range of future applications. The objective is the validation of a set of basic theoretical principles and related instructional practices that will allow students and trainees to better apply the knowledge they acquire from formal instruction to complex real-world cases--learning for use, rather than for imitative reproduction.

APPROACH: The research is guided by a theory of case-based learning and knowledge representation that stresses cognitive flexibility. Highlights of the theory's prescription for learning include: multidimensional or multiperspectival representation of cases and concepts, multiple interconnectedness within and across cases, and multiple analogies for understanding complex new concepts. A number of experiments were carried out, first to determine the conditions that produce flexibile representations and, second, to demonstrate the connection between such structural flexibility and the ability to use prior knowledge in new ways (using various measures of knowledge transfer). Paralleling the basic experiments on learning, knowledge representation, and transfer is a program of research and development investigating the effectiveness and practicality of hypertext systems (as well as studying the cognitive processes that they engage). Nonlinear and multidimensional hypertext approaches capture ill-structured aspects of knowledge domains and, thereby, promote knowledge transfer/application. Finally, because oversimplification during knowledge acquisition is a major cause of difficulty in knowledge application, a major part of our effort was devoted to identifying and cataloguing the forms in which oversimplification occurs (often unnoticed) in learning and instruction.

RESULTS AND CONCLUSIONS: We have identified a large number of pervasive misconceptions held by advanced learners, and we have traced the processes of oversimplification responsible for the development of those misconceptions. It has become evident that advanced knowledge acquisition in a subject area is in many important ways at odds with the goals and tactics of introductory instruction and with psychological biases in learning. We have developed and refined our theoretical orientation for more successful advanced knowledge acquisition, Cognitive Flexibility Theory. Aspects of this orientation that have received special study include: the use of multiple mental representations (especially the use of integrated sets of multiple analogies); the establishment of multiple alternative systems of linkage among

knowledge elements; the promotion of schema assembly (as opposed to the retrieval of precompiled schemas); and the central role of "cases of application" as a vehicle for engendering functional conceptual understanding. These various theory-based conditions for the development of cognitive flexibility (and resulting knowledge transfer ability) have been incorporated into three prototype computer hypertext systems in the areas of cardiovascular medicine, military strategy, and behavioral prediction. These systems are especially concerned with fostering the ability to apply conceptual knowledge in the context of diverse real-world cases.

CONTRIBUTIONS TO BASIC SCIENCE: This program of research addresses an important but as yet poorly understood aspect of cognitive functioning: knowledge transfer in ill-structured domains (where the application of knowledge is non-routine). Our research on cognitive flexibility contributes to basic understanding of those aspects of cognitive science that are concerned with knowledge asquisition, representation and application.

POTENTIAL APPLICATIONS: Not enough is known about the processes involved in moving a learner from the knowledge acquired from formal instruction and training to the independent application (or transfer) of that knowledge to new, naturally occurring cases. The problem of knowledge application/transfer is especially great in complex and ill-structured domains, where generic rules tend to be relatively less effective. Every kind of military training situation has some component that produces difficulty because of its complexity or ill-structuredness. Successful performance in these areas tends to come only with a considerable accumulation of case experience. Utilization of the training principles and hypertext implementations that we have been studying has the potential to reduce the amount of time required to develop advanced skill levels in these difficult areas. Besides these more general implications, our work on case-based reasoning about NATO-Warsaw Pact scenarios should enhance decision making at the operations level for that area of considerable contemporary interest to the military.

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(N): Learning, Cognition and Problem Solving
(O): Acquisition, Maintenance and Transfer of Skills

RESEARCH TOWARDS A GENERAL SKILL OF COMPUTER PROGRAMMING

MDA 903-89-K-0190   8/89 - 8/92
Carnegie-Mellon University   John R. Anderson

SCIENTIFIC OBJECTIVES: The goal of this research is to develop a theory of how the learning of one skill transfers to another skill. In addition, we want to develop an intelligent tutoring architecture which can be used to teach multiple skills and maximizes the transfer among skills.

APPROACH: We are studying the aquisition of programming skills in the languages of LISP, PASCAL, and PROLOG and the learning of one of these languages after learning another. We are building cognitive models capable of learning these skills and transferring among skills. We are also developing an intelligent tutoring system capable of training these skills and recording the aquisition of these skills.

PROGRESS: We have completed development of the tutoring architecture and completed development of a full curriculum in LISP, PASCAL and PROLOG. This have been successfully used for the first time in a classroom situation. We have also completed a series of experiments studying the transfer of solutions in one programming language to another programming language.

CONTRIBUTIONS TO BASIC SCIENCE: This research has made direct contributions to a theory human learning and transfer. The research is also making contributions to a theory of the role of representation and planning in human problem solving.

POTENTIAL APPLICATIONS: The tutoring architecture we have developed now can be used to teach programming language. We are working towards generalizing that architecture so it can be used as a general authoring system for intelligent tutors.

(N): Learning, Cognition & Problem Solving
(O): Decision Making and Problem Solving

A COGNITIVE ARCHITECTURE FOR ANALOGY AND PROBLEM SOLVING

MDA 903-89-K-0179   9/89 - 9/92
UCLA   Keith J. Holyoak
Priceton University   Paul Thagard

SCIENTIFIC OBJECTIVES: The aim is to construct an integrated computational system capable of modeling human decision making and problem solving, especially in situations involving uncertainty and incomplete knowledge. The use of analogical reasoning is viewed as a basic component of the system. The system will integrate analogical reasoning, based on retrieval of relevant past cases stored in memory, with rule-based reasoning. The model will be applied to adversarial situations that require anticipation of the probable actions of an opponent.

APPROACH: The model is based on a set of procedures for performing parallel constraint satisfaction to find solutions to such interrelated problems as retrieving relevant analogs from memory, establishing optimal correspondences between components of complex representations, matching declarative knowledge to rules, and evaluating the relative coherence of competing explanations. In parallel with the development of computational systems, experiments with human subjects will be conducted to test some important predictions of the underlying theory.

PROGRESS: During the initial five months of the project a major computational model, which will provide a significant component of the anticipated system, was completed. This is the ARCS model of analog retrieval (Thagard, Holyoak, Nelson, & Gochfeld, in press). In addition, major revisions and extensions of the ECHO model of explanatory coherence were undertaken, and the model was applied to some complex new cases of theory evaluation and naturalistic decision making. The major example of the latter type of application was a detailed analysis of the decision making involved in the Vincennes incident, as documented in the official report. During this period experimental tests of predictions of the ARCS model were conducted, which provide evidence for some of its assumptions about the process of human memory retrieval for complex material such as problems and scenarios.

CONTRIBUTIONS TO BASIC SCIENCE: The research will contribute to better understanding of the processes involved in retrieval and use of analogies, and the use of analogies in complex problem solving and decision making. More generally, the work will provide theoretical links between the fields of problem solving and decision making, which have typically been isolated from each other.

POTENTIAL APPLICATIONS: The project may provide the basis for designing computer-based aids for problem-solving and decision-making tasks that must be performed under conditions of uncertainty within an adversarial environment. Such conditions are typical of those facing Army personnel in combat and other situations. In addition, the work is expected to have applications in improving training procedures relevant to advance preparation for dealing with ill-defined and adversarial problem situations.
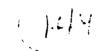
REPORTS:

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(N): Learning, Cognition and Problem Solving
(O): Decision Making and Problem Solving

LEARNING IN A REACTIVE ENVIRONMENT: AN ARTIFICIAL INTELLIGENCE APPROACH

MDA 903-85-C-0324   9/85 - 8/90
University of California, Irvine   Pat Langley
       Jaime Carbonell

SCIENTIFIC OBJECTIVES: Previous AI learning research has focused on isolated tasks and nonreactive enviroments. In contrast, we are developing an integrated model of learning in a complex, reactive environment similar to the physical world. Our learning theory focuses on issues of concept formation, motor learning, plan acquisition and the development of spatial knowledge. We are exploring these aspects of intelligence in the context of tasks involving manipulation and nagivation. We are instantiating each component as part of an integrated cognitive architecture that supports both performance and learning.

APPROACH: Our ultimate goal is a running computer simulation of problem solving and learning in a complex, physical environment. We have constructed a simulated environment that supports three-dimensional objects, gravity, friction and torque, along with a simulated robot that can perceive and affect its surroundings. We are implementing performance models for the general tasks of manipulation and navigatio·1, and we soon plan to model the acquisition of these abilities. We plan to constrain our models of learning and performance by knowledge of human cognitive and motor behavior.

PROGRESS: Our simulated physical environment now runs on color Sun workstations at both CMU and UCI, and we have developed simple agents that interact with this environment. Theoretical progress includes: CLASSIT, a model of the incremental formation of object concepts; MAGGIE, a model of skilled motor behavior and its improvement with practice; an initial model of planning and plan acquisition; and an initial model of place recognition and acquisition. We also have designs for an integrated cognitive architecture that includes these models as components.

CONTRIBUTIONS TO BASIC SCIENCE: Our research promises significant contributions to cognitive science and psychology. We hope to develop the first computational theory that relates cognitive processing to sensori-motor processing. Our theory of concept recognition and concept formation should account for a variety of phenomena, including basic-level and typicality effects. Unlike other work on motor behavior, our model makes contact with higher-level processing and is constrained by knowledge of human motor skills. Our theory of planning integrates notions of case-based and abstracted reasoning, and it augments early theories of human problem solving by showing how to acquire plans and index them efficiently. Finally, our theory of the human cognitive

architecture promises to reveal the relations between these different aspects of intelligent behavior.

POTENTIAL APPLICATIONS: A deeper understanding of human learning would significantly aid the Army's training programs. Navigation and manipulation tasks commonly arise within the Army context, and a computational model of performance and learning could lead to improved instructional methods. The work also has implications for the navigation of autonomous vehicles.

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(N): Learning, Cognition and Problem Solving
(O): Acquisition, Maintenance and Transfer of Skills

PERCEPTUAL LEARNING IN THE ACQUISITION OF FLIGHT SKILLS

MDA 903-86-C-0169   9/86-9/90
University of Illinois   Gavan Lintern

SCIENTIFIC OBJECTIVES: The goal of this research is to expand knowledge about skill learning and transfer. Most current theories of learning and transfer emphasize the notion of similarity, but the primary challenges are to identify the similarity characteristics that support transfer and to account for the fact that transfer is often better from less similar conditions. This research program is based on the assumption that enhanced sensitivity to informational properties in the environment support much skill learning and that many perceptual skills are transferred between tasks. The aim is to develop and test a theory of skill learning and transfer with specific emphasis on visually supported skills.

APPROACH: A basic flight simulation system has been developed around an IRIS real-time computer-generated visual display. This system will be used to explore perceptual learning effects and to relate those effects to the acquisition of flight skills. Two experimental paradigms are exploited. One uses experienced pilots to examine how distortions in the simulated visual scene affect performance as a means of identifying the sources of information that support flight performance. The other experimental paradigm examines the transfer of skill from a training condition to a criterion condition. The overall goal is to relate transfer effects to sources of critical information.

PROGRESS: One experiment, aimed at identifying the sources of information that support landing skills, has been completed and another is nearing completion. The first experiment showed that runway dimensions and global scene detail have significant effects on performance of a simulated landing task. By the end of the second experiment it is hoped that a more coherent understanding of the effects of multiple sources of information will emerge. One transfer experiment has been completed and the data are currently under analysis, and another is nearing completion. The first transfer experiment has shown the importance of natural representations of visual information for instruction of an aircraft landing task.

CONTRIBUTIONS TO BASIC SCIENCE: This research will contribute to an understanding of basic processes and mechanisms that support the acquisition and performance of action skills. The research program is oriented towards clarifying the informational relationship between perception and action. The potential contribution to transfer theory is outlined in a paper entitled "Transfer in manual control: An informational perspective," currently in submission to Human Movement Science. A theoretical

approach to the mechanisms of learning is outlined in the paper entitled "Self-organization in connectionist models: Associate memory, dissipative structures, and Thermodynamic Law," to be published in Human Movement Science.

POTENTIAL APPLICATIONS: Many of the problems in learning to fly result from the difficulty of acquiring new perceptual skills. The results of this work should enable the development of part-training strategies that will speed the acquisition of flight skills and that will guide the design of training simulators. The more ambitious goal is to develop procedures that can be applied to a variety of the control tasks. In addition, successful development of a perceptual theory of transfer should go a long way towards showing how a comprehensive theory of transfer can be developed. Benefits for a wide range of training activities can be anticipated.

ARCHIVAL PUBLICATIONS:

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CAUSAL MODELS IN THE ACQUISITION AND INSTRUCTION OF PROGRAMMING SKILLS

MDA 903-87-K-0652   9/87 - 8/90
Princeton University   B.J. Reiser

SCIENTIFIC OBJECTIVES: This research explores the relation between mental models and rule-based models of problem solving skill. The objective is to model the type of background knowledge that underlies problem solving rules and is needed for explanations. The instructional objective is a model of the process of explanation in tutorial interactions.

APPROACH: We are studying the problem solving and explanation process by constructing an intelligent computer-based tutor for programming. The problem solving model in the tutor incorporates condition-action rules and the underlying causal knowledge necessary for mental models. Explanations in response to student errors and questions are constructed from these knowledge representations. Planned experiments will evaluate the effectiveness of the tutor's explanation strategies and feedback.

PROGRESS: We have developed an architecture for the problem solver, explanation system, and a graphical interface for a computer-based tutor for LISP programming. (1) We constructed a problem solver that incorporates both forward and backward reasoning. Students work on the various parts of a problem in whatever order they prefer. (2) We constructed an explanation module that generates explanations by comparing the student's behavior to the information in the rule. The explanations point out the discrepancies between the legal and strategic constraints for a particular step. (3) We deve ped a graphical programming language interface for the programming constructs in the first two chapters of a LISP curriculum. Students write a program by constructing a graph rather than typing the textual form of a program. (4) We constructed a less structured version of the tutor that uses the graphical interface that enables exploration without the tutor's interruptions, in order to determine the effect of constructing a program using visual rather than a text-based representation.

CONTRIBUTIONS TO BASIC SCIENCE: The research will extend the theory of how explanations are constructed and used in instruction by human teachers, and how knowledge and strategies for explanation can be represented in an intelligent tutor.

POTENTIAL APPLICATIONS: The techniques for constructing explanations should result in more flexible tutoring systems. The empirical results should be useful in suggesting when visual representations are beneficial as problem solving aids. In addition, the tutoring system developed can be used to teach

computer programming to novices.

REPORTS:

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Reiser, B.J., Friedmann, P., Kimberg, D., & Ranney, M. (in press). Constructing explanations from problem solving rules to guide the planning of programs. To appear in <u>Proceedings of the International Conference on Intelligent Tutoring Systems</u>, Montreal, June 1988.

(N): Learning, Cognition and Problem Solving
(O): Acquisition, Maintenance and Transfer of Skills

DEVELOPING DECLARATIVE KNOWLEDGE AND AUTOMATIC COMPONENTS FOR PERFORMING HIGH WORKLOAD TASKS

MDA 903-89-K-0174   10/89 - 9/92
University of Pittsburgh   Walter Schneider

SCIENTIFIC OBJECTIVES: This research examines the acquisition of declarative rule sets, how declarative knowledge is converted into automatic procedural skills, and how those automatic skills operate in high workload domains. Experiments will examine what variables determine the difficulty of learning a rule set and identify metrics that predict the learnability of rule sets. Instructional procedures will be compared to speed initial development of automatic processing. The high workload studies will detail compensatory activities that occur in multi-task but not single task situations. Training procedures that enhance high workload transfer will be determined.

APPROACH: The research will examine both empirical and simulation studies of skill acquisition. Three empirical paradigms will be investigated. Rule learning and problem solving behavior will be studied in digital electronic troubleshooting. Students predict the output of individual gates, mini-circuits, and digital boards. A second paradigm will examine visual search tasks requiring both concurrent monitoring of and responding to targets. A third task involves rule learning and high workload performance in a simulated air-traffic control task. On all tasks initial acquisition and retention (one week and six months) will be assessed. A connectionist/control simulation will be developed for the major tasks. The simulation will test the relative effectiveness of different training procedures and identify compensatory activities for high workload performance and the learnability of rule sets.

PROGRESS: This project has begun this year. We have developed a quad-task search paradigm and examined acquisition of four tasks for high workload performance. The data illustrate substantial practice effects and workload related degradation of performance. The task should provide a good paradigm for examination of workload compensatory activities. In the simulations, we have implemented priority learning for automatic processing. This enables the stimulation to develop automatic processing.

CONTRIBUTIONS TO BASIC SCIENCE: This work will detail how the consistency of the rule set and the sequencing of practice can speed the development of automatic component skills. The research will examine competing hypotheses as to why single task training provides limited transfer to dual task situations.

POTENTIAL APPLICATIONS: The understanding of the use of declarative rules to produce automatic components will provide guidelines for training procedural tasks. The work on the maximizing transfer to high workload environments will provide specifications for building part task trainers to enhance performance in novel high workload situations.

(N): Learning, Cognition and Problem Solving
(O): Aquisition, Maintenance and Transfer of Skills

THE ANALYSIS OF EQUIVALENCE CLASSES

New Start
College of Staten Island, CUNY   Lanny Fields

SCIENTIFIC OBJECTIVES: The focus of this proposal is the analysis of the structures of different methods for training equivalence and the experimental analysis of the results of different training strategies with the objective of developing efficient and effective training methods.

APPROACH: This proposal addresses the learning of equivalences. This is a non-cognitive approach to complex conceptualizing applicable to image interpretation and other visual stimuli. An equivalence class is a concept in which the members bear little physical similarity, yet are responded as if equivalent under appropriate conditions. For example, image interpreters have to respond to vertical views, oblique views, radar signatures, and infrared signatures, among others.

Once effective methods for training equivalence are developed, they provide a methodology for instructional development and instructional authoring in many domains.

(N): Learning, Cognition and Problem Solving
(O): Decision Making and Problem Solving

TROUBLESHOOTING PHYSICAL DEVICES: LEARNING AND INSTRUCTION

New Start
Georgia Tech
Janet Kolodner
Larry Barsalou

SCIENTIFIC OBJECTIVES: This project builds on earlier ARI sponsored research to examine the ways in which novice troubleshooters became more expert with additional experience. The focus here is on examining the types of knowledge necessary for effective troubleshooting and the role and utilization of explanation and case-based reasoning.

APPROACH: By analyzing verbal protocols with vehical repair as the learning medium, the focus is one examining the types of knowledge necessary for effective troubleshooting. The effort will be significantly aided by the already accomplished development of "Mech," an instructional environment that acts as a simulator, a trainer, an external memory, and an experimental tool.

(N): Learning, Cognition and Problem Solving
(O): Acquisition, Maintenance and Transfer of Skills

GRAPHICAL REPRESENTATIONS AND CAUSAL MODELS IN INTELLIGENT INTER-ACTIVE LEARNING ENVIRONMENTS

New Start

Princeton University   Brian Reiser

SCIENTIFIC OBJECTIVES: To explore the relation between mental models and rule-based models of problem solving and to investigate the roles of visual representations and explanatory feedback in the acquisition of cognitive skills.

APPROACH: Experimental research will analyze the benefits of a graphical programming environment, including the continued development of two prototype tutoring systems, Graphical Interactive LISP (GIL) and Graphic LISP Exploratory Environment (GLEE). The use of such an environment to present intermediate products cf the reasoning process, vary the direction of problem solving, demonstrate program debugging, and assist students to visualize program execution will be evaluated.

Another sequence of experiments will evaluate the benefits of exploratory learning vs. structured learning in comparing the GIL and GLEE tutoring environments. These experiments will test the hypotheses about the mechanism by which feedback effects performance on learning LISP, and the best content for error feedback.

SPECIAL PROJECTS

Unlike the three core program areas, the Special Projects area encompasses a variety of efforts which do not fit easily within the core areas.

Special Projects may include special test of potentially "cutting edge" research; use of unique opportunities, such as rare subject populations only briefly available; and innovative methodologies, as, for example, new statistical or mathematical approaches, whose scientific applicability shows promise of extending to more than on subdiscipline of behavioral science. Another subcategory of this area is critical evaluation of research approaches and new technologies, whose scientific worth is either unclear or doubtful. Such review by high-level, impartial panels of scientists, e.g., at the National Academy of Sciences, is occasionally deemed worthy of special support.

Ancillary programs are also included, such as support for science education projects and for research at other Army institutions.

(N): Special Projects
(O): Special Projects

STUDY OF COMBAT OPERATIONS OF U.S. 7TH ARMY AND THE GERMAN ARMY

	Completed
13-ARI-86-78	6/87 - 9/88
United States Military Academy	Capt. Keith E. Bonn

SCIENTIFIC OBJECTIVES: To write a comprehensive study of combat operations of the U.S. 7th Army and the German Army Group G in the Vosges Mountains during the period October 1944-January 1945.

APPROACH: By studing the campaign through available primary sources (G3/G2 Journals of the participating U.S. units, Kriegstagebuecher of the German units, etc.), to determine which side best fulfilled their own doctrinal requirements for combat operations of the period.

RESULTS AND CONCLUSIONS: Contrary to the usually-posited reasons of materiel superiority and advantages of numbers, it was the U.S. 7th Army's superior organization, leadership, training and operational proficiency that constituted the major reasons for Allied success in this campaign.

CONTRIBUTIONS TO SCIENCE: No scholarly study of this campaign has ever been done. This constitutes the first serious study of the campaign from both sides, as well. Not even the official U.S. Army Green Book has been finished on this campaign.

POTENTIAL APPLICATIONS: The critical nature of superior training, leadership, cohesion and tactical know-how are highlighted, as is the ability of such factors to help overcome disadvantages of terrain, weather, and, in some cases, numerical inferiority.

REPORTS:

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(N):   Special Projects
(O):   Special Projects

THE EFFECTS OF MODALITY, STRESS AND TASK TYPE ON HUMAN PERFORMANCE

	Completed
ARI 13-86-78	6/87 - 9/88
U.S. Army West Point	K.L. Pamperin
University of Illinois	C.D. Wickens

SCIENTIFIC OBJECTIVES: The goal of the experiment was to investigate the effects of stress on the processing of multiple channels of information, as a joint function of the type of task served by the information (dual task or information integration) and the format of display for those channels (auditory or visual). Theories of multiple resources, perceptual tunneling, and compatibility of proximity were used as a framework for predicting the interactions between these variables.

APPROACH: Subjects were presented with a computer display that they were required to respond to based upon two items of information in the display.   In one condition, they were required to integrate the two items in order to make one decision (integration condition).   In the second condition, the subjects were required to make two separate decisions;   one decision based upon each item of information (dual task condition).   The format of information presentation was either visual (two variations) or auditory and the decisions were made under either stressed of unstressed conditions.

Although conceptually the conditions define a 3 (display format) x 2 (task type) X 2 (stress level) design, the results were interpreted as two 2 x 2 x 2 designs;   one examing the two visual display formats, the other examining cross-modal conditions.

RESULTS AND CONCLUSIONS: The results indicated that cross modal displays provided better performance than all visual displays when information integration was required, but not when dual task performance was required, and that cross modal displays were less degraded (or more improved) by stress.   Some evidence for stress induced visual tunneling was also provided and the data suggest that the benefits of stress in terms of resource expansion are more realized when resources are at a premium.

CONTRIBUTIONS TO BASIC SCIENCE: Previous research clearly suggests that stress, task type and modality of presentation all have very definite influences on human performance.   It has also been shown, where data exist, that some of the pairwise combinations of these three variables also have an impact upon human performance.   This study adds information to the existing data base by manipulating all three factors in conjunction, to identify their effects in combination.   Such data will lead to a better understanding of optimal display formatting principles when a stressful environment is anticipated.

POTENTIAL APPLICATIONS: Since a great deal of the Army's equipment is being fielded with computerized displays (visual and auditory) and it is anticipated that these systems will have to be operated successfully under conditions of severe stress (combat), the requirement for information concerning optimal display formats is obvious. These results may be applied to systems such as helicopter cockpits, tank cupolas, air defense artillery monitoring systems, air traffic control systems, etc., where computerized displays are being used to present information to human operators in a potentially stressful environment.

There are three specific practical implications of this research. First, there appears to be a relative advantage to presenting information in separate modalities when stress is applied. From the designer's perspective, this phenomenon would favor the offloading of more visual information to the auditory channel in conditions of elevated stress.

The second implication concerns the differential effect of stress across task type. Although these data cannot be used to determine whether the differences in stress effects between the two task types (integrated and dual task) is the result of differences in processing quality (intergration vs. dual), decision complexity (greater for the integration task) or total processing demand (greater for dual task), the data do suggest caution in assuming that tasks of greater resource demand will inevitably suffer greater effects of stress. Hence, even though the subjects perceived the dual task condition as being more demanding, it was the integrated task performance which suffered greater degradation under stress.

The third implication involves the differential effects of stress on visual presentations across task types. The display designer should be aware that, when using multiple channels of visual information, care should be taken to select the most essential information for foveal display when increased stress is anticipated because of the phenomenon of visual tunneling. When the information had to be integrated, however, the distribution of visual elements across the display did not interact with stress.

REPORTS:

Pamperin, K.L., & Wickens, C.D. (January, 1988). The Effects of Modality, Stress and Task Type on Human Performance. Technical Report (Draft) 88-1. Champaign-Urbana, IL: Army Human Engineering Laboratory.

Pamperin, K.L., & Wickens, C.D. (October, 1987). The Effects of Modality, Stress and Task Type on Human Performance. Proceedings of the 31st Meeting of the Human Factors Society. New York, NY.

(N): Special Projects
(O): Special Projects

APPLIED TECHNOLOGY AND SECOND LANGUAGE LEARNING

ARI 13-86-78

U.S. Military Academy

Completed
6/87 - 9/88

Robert A. Quinn

SCIENTIFIC OBJECTIVES: Review currently available software in terms of its applicability and its pedagogical orientations. Develop and delineate the roles of computer-assisted language learning (CALL) and interactive video (IAV) in the learning environment particular to West Point. Develop working hypotheses relating to appropriate levels for various media. Identify the most feasible hardware/software configurations, particularly with reference to the Cadet Personal Computer. Design, test and evaluate pilot programs in the West Point curriculum in foreign languages. Instruct USMA faculty in the effective use and individual tailoring of CALL and IAV to their courses. Define and develop standardized systems of programs for instruction for cadets.

APPROACH: Undertake a significant effort to find, evaluate and use software, particularly authoring systems, suited to USMA's purposes. Carry out extensive archival research and attend leading professional conferences focusing on CALL and IAV. Conduct pilot studies and a large-scale empirical study, as well as survey students as to their needs and preferences in CALL lessons. Use authoring systems to develop CALL lessons involving an extensive variety of pattern and substitution exercises for German, Spanish, Russian and Portuguese, then test them within the instructional environment. Develop prototype video lessons and formulate the most feasible procedures for integrating them into the language curriculum.

RESULTS AND CONCLUSIONS: It was decided that most software available for foreign languages was not pedagogically suitable and that we should develop our own. CALIS was selected as our primary authoring system for CALL, and IconAuthor (Maestro) was determined to be best suited for our video needs. A supplementary CALL system, DFLash, was developed and tested in-house. Generalized conclusions based on the studies we conducted will be used to further revive CALL lessons and make them more pedagogically effective as well as more conducive to cadet use. Archival research and participation in conferences have shown that our findings on improving retention are corroborated by studies at other institutions of higher learning. Extrapolating these findings, we have begun to design computer exercises that will prepare cadets to use contextual clues, acquire essential cultural information, and improve their comprehension of an interactive presentation which is rich in authentic audio-visual stimuli and which might overwhelm unprepared students.

After successfully resolving numerous technical details involved in the compatibility of the computer and peripherals, a configuration based on the Cadet PC and Visage System was selected. Meetings were held to familiarize faculty members with CALL and IAV. Preliminary guidelines for writing methodologically-sound CALL programs written with CALIS have been drawn up and distributed to the D/FL faculty.

CONTRIBUTIONS TO BASIC SCIENCE: We have found and exploited practical authoring systems to produce economical, pedagogically-sound lessons for both CALL and IAV. These can be used as systems and models for designing effective coureware for subjects, such as English, History, Law and Psychology, in which the use of the spoken and written word plays a key role. As a result of this research, we have firmly established that pedagogy--not technology--must be the driving force in the development of CALL and IAV lessons. Rather than focusing on the hardware itself, we must concentrate on the most effective ways of using it in order to deliver course material. Teachers have to be trained in its proper use before they can produce effective lessons.

This research has also provided a much clearer perspective of our student's needs, attitudes and learning preferences, as well as a keener appreciation of the limitations and advantages of computer-assisted instruction for enriching and improving the quality of the cadets' academic experience. Preliminary indications are that CALL should be used at the introductory and intermediate levels, while IAV supported by CALL should be used at the intermediate and higher levels. A multimedia curriculum integrating the use of textbook, audio, computer and video materials and coupling them with the most suitable methods at the appropriate times now appears to be the most promising approach for a maximally effective instructional program.

POTENTIAL APPLICATIONS: As technological advances in communication and travel facilitate rapid contact among all areas of the globe, foreign languages are becoming more and more strategically important. Also, as the Army becomes increasingly technologically-oriented and the U.S. Military Academy invests substantial funds to make computers available for administrators, instructors and cadets, it is imperative that our technological resources be used effectively. Whether used alone or in conjunction with peripherals such as videodisc players, the microcomputer promises to improve dramatically both teaching and learning. The results of this study can assist in realizing the potential offered by computers, not only for instruction in foreign languages but also for more efficient learning of subject matter in which the written and spoken word play a key role and in which their accurate use is essential. Moreover, the findings of this research can be extrapolated to enhance the design and implementation of computer-assisted learning, not only for cadets studying in various departments at USMA but also for soldiers at numerous training centers in the modern Army.

REPORTS:

Quinn, R.A. (August 1987). Computer-assisted Instruction
for Portuguese: Examples and Exercises. Paper presented to
Portuguese Language Development Group, American Association
of Teachers of Spanish and Portuguese, Los Angeles, CA.

Quinn, R.A. (October 1987). Producing Quality Software within
the Foreign Language Department. Paper presented to Special
Session: Computer Applications in English and Foreign
Languages, South Central Modern Language Association,
Houston, TX.

Quinn, R.A. (February 1988). Progress Report on Research and the
Implementation of TALL (Technologically-Assisted Language
Learning). Paper presented to the Federal Agency Annual
Review, CALICO (Computer Assisted Language Learning and
Instruction Consortium). Convention, Salt Lake City,
UT.

Quinn, R.A. (May 1988). Applied Technology in Second
Language Learning: The Effective Use of the Multimedia
Laboratory Research seminar sponsored by the Office of the
Dean, USMA.

Quinn, R.A., & Kahn, R.J. (August 1988). Techniques for Teaching
Reading via the Microcomputer. Paper presented to the
Continuing Session: Computers in Research and Training,
American Association of Teachers of Spanish and Portuguese,
Denver, CO.

ARCHIVAL PUBLICATIONS:

Quinn, R.A. (Summer 1987). Major sources of Information for
Computer-Assisted Language Learning. In Software
Listings and Reviews. MLA Newsletter, 19, (2).

Quinn, R.A. (1988). Practical Approaches to Integrating Modern
Methods and Media for a More Successful Language Learning
Experience. Hispania, 71, (4).

(N): Special Projects
(O): Special Projects

DISCRIMINATIVE ENVIRONMENTAL PROPERTIES IN TERRORIST ENVIRONMENTS- A BASIS FOR TRAINING

Completed
DAJA 45-88-C-0001   9/87 - 6/90
University College, Cork, Ireland   Maxwell Taylor

SCIENTIFIC OBJECTIVES: The project seeks to identify and describe environmental and contextual cues available to experienced security force personnel which may be associated with terrorist threat.

APPROACH: Within the context of applied behavioral analysis, the approach is to:

    a. analyze a range of incidents to identify potential discriminative environmental properties;

    b. conduct a series of observations, and undertake experimental investigations of the role and use of discriminative cues in selected simulated settings.

Analysis of incidents have been completed in several settings. Experimental analysis of simulated incidents have focused on relatively simple settings, progressing to more complex situations.

RESULTS AND CONCLUSIONS: Operational problems in some of the local settings initially delayed incident analyses. These were resolved and the analyses have now been satisfactorally completed. A series of experimental investigations have been conducted, meeting both the first objective of identifying discriminative environmental qualities, and the second objective of investigating the use of discriminative cues in simulated settings.

CONTRIBUTIONS TO BASIC SCIENCE: These studies will contribute to the applied analysis of behavior in complex environments. It will extend knowledge of the discriminative control of complex environmental events over risk related human behavior, and will in addition develop a behavioral approach to the analysis of experience. The approach emphasises the role of rule governed versus contingency control of behavior. The studies will assist in the formulation of systematic empirically based training objectives and procedures.

POTENTIAL APPLICATIONS: The project may contribute to both operational and training issues related to the management of personnel in hostile settings.

ARCHIVAL PUBLICATIONS:

Taylor, M. (1988). <u>The terrorist</u>. London: Brassey's Defence Publishers.

Taylor, M. (in press). <u>Fanatical political violence</u>. London: Brassey's Defence Publishers.

Taylor, M. & Rayan, H. (1988). Fanaticism, political suicide and terrorism. <u>Terrorism</u>, <u>11</u>, 91-111.

Ryan, H. & Taylor, M. (1988). Information usage and cue identification as a function of experience in police officers. <u>Journal of Police Science and Administration</u>, <u>16</u>, 177-181.

(N): Special Projects
(O): Special Projects

CONGRESS AND DEFENSE REORGANIZATION

Completed
13-ARI-86-78   1/88 - 12/88
United States Military Academy   Andrew B. Twomey

SCIENTIFIC OBJECTIVES: This research will examine congressional action with regard to the organization of the Department of Defense. A detailed examination of congressional action on this topic will serve two objectives. It will illustrate, first, the changed nature of congressional involvement in defense policy and second, the changed incentive structure and environment for individual congressmen/senators to take action on structural defense issues.

APPROACH: The three specific cases to be examined are the National Security Act of 1947, the amendments of 1958, and the Goldwater-Nichols Act of 1986. These cases comprise the only instances of both significant organizational change and congressional involvement. The use of these three comparable cases will allow examination of the same dependent variable--congressional involvement in reorganization. The dependent variable exhibits significant variance and the issue is one in which the most common independent variable for explaining congressional actions--reelection concern--is markedly absent. A variety of other potential independent variables, for example the structure of Congress, remain constant across all three cases. Investigation of these cases will entail both archival research and interviews with key individuals, particularly with respect to the Goldwater-Nichols Act.

RESULTS AND CONCLUSIONS: A series of interviews were conducted in Washington, D.C. with present and former congressional staff concerned with defense reorganization in June and July of 1988. Archival research was conducted during the period of Jan-June 1989. A draft article has been completed and is being reviewed at this time (March 1990).

CONTRIBUTIONS TO BASIC SCIENCE: A standard of congressional literature is the assumption of a desire for reelection as the primary incentive for a member's individual behavior. Most authors find this lack of incentive to be a crippling defect for congressional action on substantive as opposed to "pork barrel" defense policy issues. Reorganization as an issue is an important case because electoral concerns are either absent or exceptionally well camouflaged. The benefits to be delivered to the district from reorganization are nil; therefore at the individual level explanations of congressional behavior must rely on other motives. Thus in the field of political science the potential contribution of this research is the indentification and explanation of individual motivations in Congress.

POTENTIAL APPLICATIONS: The increased activity of individual congressional representatives/senators on defense issues will have a significant impact on the U.S. Army. This research will assist individuals concerned with responding to congressional requests and directions by providing an understanding of the institutional and environmental motivations for action.

(N): Special Projects
(O): Special Projects

BASIC RESEARCH ON HUMAN FACTORS

SCIENTIFIC OBJECTIVES: The Committee on Human Factors was established as a standing committee of the National Research Council to provide new perspectives on theoretical and methodological issues and to provide guidance to its sponsoring federal agencies on matters concerned with the research needed to expand the scientific foundation and application of human factors.

APPROACH: The Committee advises its sponsors regarding the most important basic research needs and provides guidance on methods for investigating them. It convenes and manages the efforts of working groups, panels, seminars and symposia and invites the major scientists in the topics under investigation to participate in these studies. Study group members are directed to explore the state of knowledge in areas judged by the Committee and/or its sponsors to be of particular importance and to develop detailed research agendas for filling gaps and for advancing scientific knowledge. In addition, the Committee provides a mechanism for encouraging contact and communication among both basic and applied researchers in the United States and abroad.

RESULTS AND CONCLUSIONS: During the reporting period, the Committee completed a study on human factors research issues for an aging population. This study investigated the effects of the aging process on the performance of critical daily tasks, and the report of the study suggests promising lines of research to arrive at human factors solutions based on adaptation, compensation and remediation. In addition, work continued on studies of multicolored displays, human performance modeling, distributed decision making, and expert systems. Reports of these studies are scheduled for publication early in 1990. The Committee has also undertaken studies in the areas of human error, the augmentation of human intellectual functioning by computer, organizational productivity, and enhancing employability of the disabled in information work. It is anticipated that reports of these studies will be published in 1991 and 1992.

CONTRIBUTIONS TO BASIC SCIENCE: The mechanisms underlying human behavior can only be fully understood and modeled when that behavior is considered within the context of purposive human tasks. In today's technological world, many of these tasks are performed in conjunction with complex systems. The studies of the Committee contribute to science by revealing the strengths and weaknesses of existing psychological knowledge and by pinpointing the basic research needed to understand, describe and predict how humans perform in complex environments.

POTENTIAL APPLICATIONS: Each of the Committee's studies provides a conceptual bridge between theories of human behavior and the design and operation of the human-technological systems that the Army employs to carry out its missions. For example, studies of how multi-colored displays should be designed to exploit human vision, of how computer software should be designed to be compatible with human mental models, and of how human anthropometry and biomechanics place constraints on equipment design are applicable whenever data are displayed and processed for use by Army personnel in different work stations and work contexts.

ARCHIVAL PUBLICATIONS:

Baron, S.; Kruser, D. S.; and Huey, B. M. (Eds.). (1990) Qualitative Modeling of Human Performance in Complex, Dynamic Systems. Washington, D.C.: National Academy Press.

Committee on Human Factors. (1990). Distributed Decision Making: Report of a Workshop. Washington, DC: National Academy Press.

Czaja, S. (Ed.), (1990). Human factors research issues for an aging population. Washington, DC: National Academy Press.

Elkind, J. I.; Card, S. K.; Hochberg, J.; and Huey, B. M. (Eds.). (1990). Human Performance Models for Computer-Aided Engineering. Boston, MA: Academic Press. (Also published in 1989 by National Academy of Press, Washington, DC).

Kinney, J. S.; and Huey, B. M. (Eds.). (1990) Application Principles for Multicolored Displays: A Workshop Report. Washington, DC: National Academy Press.

(N): Special Projects
(O): Special Projects

A THEORY OF INFERENCE DERIVATION FROM QUALITATIVE DATA: DEVELOPMENT AND TEST WITH APPLICATION TO CRIMINAL AND TERRORIST DETECTION

DAJA 45-88-C0021   10/89 - 10/90
University of Surrey   D. Canter

SCIENTIFIC OBJECTIVES: The research aims to develop a system for inference derivation from qualitative data using intermediate representations. Traditional decision support systems are directed at summarizing material which is amenable to quantitative analysis of costs and benefits. The present work is focused on the visual representation of both task and process in group decision making, so that critical aspects of a group's decision structure can be fed back as an aid to decision making.

APPROACH: Groups are being studied using structured and unstructured knowledge elicitation techiques, and a number of different types of representational systems. Groups without representational feedback are also being studied in order to assess the efficacy of the representational feedback system. Psychological variables such as communication and group cohesion are being studied in addition to the decision makers' perceptions of the group's success in terms of task focus and problem solving techniques. Particular attention is given to the structuring of qualitative data *derived from the records of* serious crimes. Representations of such data are being assessed with a view to their possible application in linking criminal activity during police investigations.

PROGRESS: The research has developed an understanding of the way in which critical aspects of a decision problem can be represented using two representational systems for qualitative data: Multidimensional Scalogram Analysis (MSA), and Partial Order Scalogram Analysis (POSA). By working with both hypothetical decision making data from experimental groups and existing data from real decision making tasks, it has been possible to show how the system would represent both the similarities and differences between qualitatively different decision options, and possible areas of agreement and conflicting viewpoints between individuals in the decision making group. Work with hypothetical decision making groups has shown that when knowledge of the decision problem is elicited from the group members prior to the decision being made, representation can model both the task and group process dimensions of their subsequent interaction. Initial studies indicate that feedback of such modelling will be valuable as an aid to group decision making.

CONTRIBUTIONS TO BASIC SCIENCE: 1) The development of representations for qualitative aspects of expert knowledge, in particular the development of representations which are able to encapsulate the knowledge of an expert group as well as its individual members, will be of importance to knowledge engineering and expert systems. 2) The development of a system which is capable of modelling the group decision making process on both task and group process dimensions is a valuable contribution to decision making research in applied social psychology.

POTENTIAL APPLICATIONS: The research points directly to the development of an integrated decision support system for various types of qualitative data, which would be of use for both group and individual decision making in structuring complex knowledge bases. Additionally, modelling of the decision process has considerable potential for training in decision making. The developments made in the structuring of qualitative data regarding criminal activity also have implications for the study of criminal development and on inferences made regarding the linking of serial crime.

REPORTS:

Canter, D.V., & Wilson, M.A. (March 1989). A Theory of Inference Derivation from Qualitative data: Interim Report. Technical Report, University of Surrey, Guildford UK.

Canter, D.V., & Wilson, M.A. (October 1989). A Theory of Inference Derivation from Qualitative data: Summary Report, Year One. Technical Report, University of Surrey, Guildford UK.

Wilson, M.A. (October 1989). Developing a System for Decision Support. Paper presented at Helping People Make Better Decisions: What can Psychology Contribute? University of Surrey, UK.

Canter, D.V. (January 1990). The Facet Approach to Criminal Investigation. Paper presented at FBI Academy, Quantico, Virginia.

Canter, D.V. (February 1990). Helping the Police with their Enquiries: Fact and Fiction in Offender Profiling. Paper given to Medico-Legal Society, Manchester, UK.

Canter, D.V. (March 1990). Multivariate Approaches to Offender Profiling. Paper presented at International Symposium on forensic Science. Punjab University, Patiala, India.

(N): Special Projects
(O): Special Projects

CHARACTERISTICS OF TRANSFORMATIONAL LEADERS

814721.12Z39(ZN39)   10/87 - 9/88
United States Military Academy   Louis S. Csoka

SCIENTIFIC OBJECTIVES: The object is to extend our present theoretical understanding of the leadership process by research into one of the newer approaches to leadership as developed by Bernard Bass. Transformational leadership focuses on the nature of the individual as leader and attempts to identify those essential characteristics that bring about extraordinary performance. Significant factors that delineate trans- formational leadership have been identified by Bass and others.   Whether or not such leaders are qualitatively different and if so, in what way, is the object of this study.

APPROACH: The approach is to conduct surveys of battalion and company commanders and their subordinates to obtain data on the transformational factors for the leaders and their psychological profiles and relate these to each other as well as to some performance criteria.   Two instruments are being used to assess the leader factors and the profile: Bass' Multifaceted Leadership Questionnaire (MLQ) and Cattell's 16 PF Questionnaire.   All battalion and company commanders rotating through the National Traing Center (NTC) in FY B7-BB are being measured on both the MLQ and the 16 PF.   Criteria measures come from the unit's performance during the NTC evaluation. Questionnaires are collected through the Army post points of contact who administer the instruments and return by mail to the principal investigator.   Analyses are currently being conducted to generate the profiles and to find relationships among performance, transformational leadership factors, and psychological profiles.

PROGRESS: Questionnaires have been distributed and returned. Data collection of performance measures at the NTC was delayed due to budget issues which forced units to delay their NTC cycles. Analysis is in final stages and a report will be completed by July 1990.

CONTRIBUTIONS TO BASIC SCIENCE: Results will advance our knowledge of the leadership process by incorporating transformational factors in identifying leaders who attain performance beyond expectations.   In addition, the derived psychological profile will describe the characteristics of such leaders.   This is the first test of the newly developed transformational model against objective performance criteria.

POTENTIAL APPLICATIONS: Results could be applied to leader training and leader development programs and to leader self-assessment programs at the Command and General Staff College and the Army War College.

(N): Special Projects
(O): Special Projects

TECHNIQUES FOR THE ENHANCEMENT OF HUMAN PERFORMANCE

MDA 903-89-K-0088   3/89 - 12/90
National Research Council   D. Druckman

SCIENTIFIC OBJECTIVES: Provide guidance regarding appropriate
scientific criteria for evaluating claims (e.g. self-insight guides
and altered-mental states) on techniques for the enhancement of
human performance and the kinds of research needed to advance
understanding of the scientific principles on which these
techniques are based.

APPROACH: 1) Develop a classification of existing techniques for
the enhancement of human performance according to the theoretical
principles on which they are based; and 2) Review and assess the
relevant scientific literature, both theoretical and empirical,
underlying the techniques in each major area (experimental,
physiological, clinical, social, and industrial psychology and
cognitive science).

PROGRESS: Findings will be presented in the committee's report.

CONTRIBUTIONS TO BASIC SCIENCE: It will capture the state of the
art on these topics with important implications for application.

POTENTIAL APPLICATIONS: Recommendations for evaluation and design
of training programs.

ARCHIVAL PUBLICATIONS:

Enhancing Human Performance: Issues, Theories and Techniques,
     National Academy Press, 1988.

(N): Special Projects
(O): Special Projects

RESIDENT RESEARCH ASSOCIATESHIP PROGRAM

New
MDA 903-87-C-0752   9/89-8/90
National Academy of Science   Thomas C. Rozzell

SCIENTIFIC OBJECTIVES: Provide high quality postdoctoral
researchers for independent research in ARI laboratories.

APPROACH: Through national and international competition, the NRC
solicits applications from graduate students or senior scientists
for research, largely of their own choosing, to be performed in the
laboratories of the Army Research Institute. The applicants are
evaluated by a highly selected panel of scientists drawn primarily
from the academic community. After evaluation, those that are
deemed to be above a pre-determined level of competency and
scientific promise are recommended for awards. The NRC makes
awards in consultation with ARI and pays all moving and stipend
expenses as well as handles health insurance and professional
travel for the researchers. The researchers, known as NRC Research
Associates, are guest investigators in the ARI labs during their
tenure, which may last as long as three years at the discretion of
the Army Research Institute, and are not employees of the Army.

PROGRESS: To date, awards have been given to nine associates.
Several applicants are in the process of being reviewed.

(N): Special Projects
(O): Special Projects

TECHNICAL AND ANALYTICAL SUPPORT FOR THE U.S. ARMY INSTITUTE

MDA 903-88-C-0054   6/88 - 5/93
Consortium of Universities   Robert S. Ruskin

SCIENTIFIC OBJECTIVES: The overall objective is to provide technical and analytical support for the conduct of ARI's in-house research. Area universities contribute to a variety of research projects and provide various technical and analytical support services.

APPROACH: The Consortium provides technical and analytical support through three primary mechanisms: (1) The Consortium employs graduate students in the social sciences to act as research assistants to the scientists at ARI. These students are identified through the graduate departments at member institutions, screened by the Consortium, and matched to appropriate positions at ARI. Known as Consortium Research Fellows (CRFs), they are guided in their research by scientists at ARI and given overall supervision by the Consortium's Project Director. (2) Consortium faculty (Senior Consortium Research Fellows) also provide assistance to ARI. This takes two forms. In some cases, faculty work individually with scientists at ARI. In others, faculty provide expertise and laboratory facilities at their institutions in order to undertake research projects directed by scientists at ARI. (3) The Consortium developed and maintains a Faculty Expertise Database representing the faculty of its member institutions and other schools in the Washington Metropolitan Area. ARI uses the database to identify persons with the particular expertise, experience or capabilities necessary to provide assistance on a given research task.

PROGRESS: This project has increased in both size and scope over the past year: the number of CRFs has increased from 25 to 48 and they represent more disciplines than ever before, including economics, computer science, psychology, and sociology; CRFs are working in BRO, MPRL, PP&O, SRL, TRL, both in Alexandria and at Ft. Bliss, Ft. Gordon, Ft. Knox and Orlando; two research tasks are now in progress in university laboratories (University of Maryland-College Park and George Mason University); the Faculty Expertise Database includes 1,700 faculty resumes and continues to grow.

CONTRIBUTIONS TO BASIC SCIENCE: Given the wide-raging nature of the technical and analytical assistance provided, the major contributions to basic science are best represented by the papers co-authored by CRFs and listed on the "Reports" and "Archival Publications" sections below. Another contribution is the Office of Basic Research in-house database developed within this contract.

POTENTIAL APPLICATIONS: The assistance provided by the Consortium directly enhances ARI's effectiveness and productivity, therefore contributing to the larger Army mission.

REPORTS:

Bui, K.B. (1988). Hyperlexicon: A hypermedia-based lexicon for vocabulary acquisition. Paper presented at 2nd International Conference on Computer-Assisted Learning (ICCAL'89), 9-11 May 1989, Dallas, TX.

Chance, D.K., Tremont, P.J., & Sanders, M.G. (1989). A procedure guide for mobile subscriber radio terminal operation. Army Research Institute: Ft. Gordon Field Unit.

Christ, R.E., Conroy, J., Robertson, R., & Kellner, A.J. (1989). The Crew Requirements Definition System (CRDS). Abstract in Proceedings of the Army Operations Research Symposium.

Dancho, N.N. (1989). Training program refinement for a prototype command, control and communications system: Soldier requirements, performance and feedback. Unpublished Master's thesis.

Graham, S.E., Leet, W.T., Elliot, G.S., Hamill, J.P., & Smith, S.E. (1989). Soldier performance research project: Armor field and SIMNET tests. (Draft Research Report). Ft. Knox, KY: U.S. Army Research Institute.

Hawkins, P., & Kronheim, S.P. (1989). User guide for the Office of Basic Research contract report search system. Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Hopkins, R. (1988). Training for transfer: A metacognitive and learning-strategies approach. Working paper. Alexandria, VA: U.S. Army Research Institute.

Julien, T.D. (1989). Army leaders' views on the Joint Readiness Training Center. ARI Research Note. Alexandria, VA: U.S. Army Research Institute.

Kronheim, S.P. & Ruskin, R.S. (1990). How it works: Some recent developments in the pursuit of academic excellence. Alexandria, VA: U.S. Army Research Institute.

Morrison, J.E. & Walker, S.A. (1989). The effects of mental practice on tank gunnery performance. (HumRRO Interim Report IR-PRD-89-10). Alexandria, VA: Human Resources Research Organizations.

Mutter, S.A., Swartz, M.L., Psotka, J., Sneed, D.C. & Turner, J.O. (1988). Changes in knowledge representation with increasing expertise. ARI Technical Report 810, 2Q263744A794. Alexandria, VA: U.S. Army Research Institute.

Oliver, L.W. & Julien, T.D. (1989). Leader perceptions of the Joint Readiness Training Center experience. ARI Research Note. Alexandria, VA: U.S. Army Research Institute.

Oliver, L.W. and Julien, T.D. (1989). Leader perceptions of the JRTC experience: Findings from a recent rotation. Paper presented at the annual meeting of the Military Testing Association, 7 November 1989, San Antonio, TX.

Orasanu, J., Ryaby, P., Link, T., & Fisher, P. (1989). Stress, stressors, and performance in military operations: A review. (DTIC Tech Report). Alexandria, VA: U.S. Army Research Institute.

Ruskin, R.S., & Kronheim, S.P. (1990). Innovative instructional strategies: Successful learning systems for military and civilian educational environments. Alexandria, VA: U.S. Army Research Institute.

Shipman, M.G. & Finley, D.L. (1989). Military occupational specialty (MOS) restructuring: An annotated bibliography. Fort Gordon, GA: U.S. Army Research Institute Field Unit.

Smith, S.E. & Graham, S.E. (1989). Comparability of a field and SIMNET test of combat performance. Paper presented at the Military Testing Association Conference, 7 November 1989, San Antonio, TX.

Steinberg, A.G. & Leaman, J.A. (1988). The Army leader requirement task analysis: Noncommisioned officer results. LMTA Working Paper 88-07. Alexandria, VA: U.S. Army Research Institute.

Steinberg, A.G. & Leaman, J.A. (1988). Army leader requirements and the technical/interpersonal/conceptual model. Paper presented at the 96th Annual American Psychological Association Conference, 14 August 1988, Atlanta, GA.

Steinberg, A.G. & Leaman, J.A. (1988). The leader requirements survey: Supplementary NCO data. (LMTA Working Paper 88-08). Alexandria, VA: U.S. Army Research Institute.

Steinberg, A.G. & Leaman, J.A. (1989). Army leader requirements: Are they sequential and progressive? Presented at the Leadership Conference of the Center for Army Leadership, 12 April 1989, Kansas City, MO.

Steinberg, A.G. & Leaman, J.A. (1989). Dimensions of Army commissioned and noncommisioned officer leadership. Presented at the 97th Annual convention of the American Psychological Association, New Orleans, LA.

Steinberg, A.G. & Leaman, J.A. (1989). Army leadership dimensions. Presented at the 31st Annual Military Testing Association Conference, 7 November 1989, San Antonio, TX.

Swezey, R.W., Llaneras, R.E., Perez, R.S., & Gittleman, S.G. (1989). Relationships among maintenance skill level and use of various levels of information complexity, in verbal and graphic components of a computerized job performance aid. SAIC Report No. SAIC-89-05-178.

Westerman, D.A. & Ramsay, D.A. (1989). Learning Morse Code characters: A replication of the Keller Method. Research Note. Alexandria, VA: U.S. Army Research Institute.

Wiggs, C. (1988). Evaluation of training of device effectiveness: An application and validation of four predictive models. Alexandria, VA: U.S. Army Research Institute.

ARCHIVAL PUBLICATIONS:

Wiggs, C. & Perez, R.S. (1988). The use of knowledge acquisition in instructional design. <u>Computers in Human Behavior</u>, Vol.4, 257-274.

MANAGEMENT IN THE 1990'S

SCIENTIFIC OBJECTIVES: The Army's Office of Basic Research and Construction Engineering Research Laboratory (CERL) joined other corporate and government agencies to sponsor jointly a civilian research program examining the impact of future technological developments in information communications, automation and computerization on organizational management. The Sloan School of Management at MIT carried out this five year effort.

Goals of the program include understanding how organizations acquire, develop and deploy new skills. The Army and the private sector need to know more about what strategic options are available for alternating organizational mission and business. It is important to examine the relationship of information technology to the ways in which organizations are structured. Acquiring information about the managerial processes (personnel development, planning and control, etc.) and systems requires to match new organizational forms is also vital.

APPROACH: Basic Research collaborated with various sponsors to develop scenarios depicting possible future organizational environments. Establishing managerial guidelines represented one important line of inquiry. Another direction included projects examining the effective use of information networks and identification of the conditions affecting their use. The program also sought to understand the range of information technology and the rate of change likely to be adopted.

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INDEX OF PRINCIPAL INVESTIGATORS