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DECISION MAKING TEAMS: THEIR STUDY IN THE U.S. MILITARY

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13. ABSTRACT *(Maximum 200 words)*

Decision making plays a major role in effectiveness at all levels within an organization, from the decision made by the worker performing primary production or service activities to the Board of Directors whose members make strategic decisions about the future directions of the firm. Often the critical decisions are made in teams rather than individually. A major portion of the research on team decision making has been dome in the military with tactical teams performing in simulated exercises. TActical decision making is typified by a hierarchical structure with a leader and team members who possess specialized knowledge relevant to the decision ultimately made by the leader. This specialization of knowledge within the team is referred to as "distributed expertise." Hierarchical teams with distributed expertise are also common in other public and private organizationas. The purpose of this review is to identify critcal findings regarding the effectiveness of such teams and to draw conclusions regarding them in nonmilitary as well as military settings.

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Tactical Decision Making Teams: Their Study in the U.S. Military

There is a clear trend in business and industry toward shifting work from individuals to teams (Cespades, Doyle, & Freedman, 1989; Dumaine, 1990, 1991; Kiechel, 1991). A recent Wall Street Journal article reported two thirds of big companies use senior management teams for innovative decision making, up 25% from 10 years ago ("Teams," 1991). Some examples are companies with autonomous senior management teams serving as temporary CEOs (AT&T), self-directed management teams in manufacturing, administration, and R&D (Kodak), and cross-functional leaders for senior management teams (New York Life). The Wall Street Journal also reported on self-managed teams at Chrysler Corp that led to subsequent drops in absenteeism, grievances, and defects (Lublin, 1992), and Deming's Total Quality Management principles to enhance teamwork (Deming's Demons, 1990). Harvard Business Review has detailed IBM procedures to establish team processes through Process Quality Management (Hardaker & Ward, 1991). Even public service agencies such as the U.S. Postal Service ("Worker Input", 1990), are implementing "employee involvement teams." In other cases teams paired with some workforce restructuring improved productivity and service at companies such as Citicorp, Corning Inc., Eastman Kodak, and Maxwell-Macmillan Group ("Firms Cut", 1990). Along with the successes are some failures (Drucker, 1992).

Although testimonials abound regarding team successes and failures, they provide little for understanding how and what works well regarding team effectiveness. More rigorous research is needed to evaluate team based structures and to isolate factors that can be manipulated to enhance their effectiveness.

Factors that have been examined in recent research are numerous and varied. Variables addressed in six leading academic journals in the past 5 years are shown in Tables 1, 2, 3, and 4. As is apparent, organizational research on teams is widespread and varied in its focus.

Many of the teams studied in Tables 1-4 performed tasks that can be labeled as "tactical decision making" (TDM) tasks. TDM tasks can be defined as those where choices are made among alternative courses of action when there is a large amount of information from differentiated sources of experts, where the choices must be integrated through a hierarchical decision-making structure in order to reach a team decision. Such conditions cover a large number of teams in work settings. Some examples of TDM tasks in business would include:

1. A strategic planning team composed of top executives from Finance, Marketing, and Operations, led by the CEO with the task of considering alternative relationships (from short-term contracts to acquisition of the company) with a supplier.
2. A team composed of a tax analyst, a labor market analyst, and a marketing executive, with a corporate strategy leader, meeting to consider alternative plant locations.
3. A team composed of legal, human resource, and public relations experts created for the purpose of ascertaining the best course of action to take with regard to a complaint of age discrimination filed against the company.

That organizational researchers are focusing on TDM issues is good. It is argued here that those concerned about team decision making effectiveness could learn much from a greater knowledge of the research work performed in military contexts. The researchers within the military have had a long-standing interest in tactical decision making and a great deal of work already exists on this topic.

Current military research is focused on team tactical decision making with regard to (a) aircrew coordination and decision effectiveness and (b) scenarios related to command, control, and communication (C3) effectiveness. Command, control and communication is a broad term encompassing the collection, coordination and consideration of military tactical information, often complex with short timelines for decisive action. Such decisions include many facets of combat readiness and response, from the broad perspective of battlefield logistics to specific decisions to engage a weapon system against threat. Both aircrew and C3 scenarios include high complexity, high volume information flow, interdependency of team members, and time constraints for decision making. Incoming information is often ambiguous; thus, the TDM decision process usually begins with environmental assessment and problem formulation.

There are many parallels between teams within the business organizations and military C3 teams. Sundstrom, De Meuse, and Futrell (1990) describe differing characteristics of work groups and provide a taxonomy that allows one to explore these parallels. Their taxonomy is based on team purpose, work-team differentiation, external integration, work cycles, and typical outputs. Tactical decision making teams are placed in the same category as negotiating teams, that of action/negotiating teams, characterized by (a) high differentiation of expertise (expert specialists), (b) high levels of integration (synchronization within and outside the organization), and (c) brief performance events often repeated under new conditions.

The relevance of TDM research findings may be more apparent when one considers the issues under investigation. TDM issues include the effects of information overload, information degradation, and stress on team processes and outcomes. As is apparent from Tables 1-4, related issues currently addressed by academic management researchers include effects of individual differences, team structure, communication processes, decision processes, cognitive models, and training interventions. Most, if not all, of the latter team research streams are likely to be informed by knowledge gained in TDM research.

Given the analogous tasks confronting hierarchical teams with distributed expertise regardless of setting, much of the research on TDM teams sponsored by various branches of the military may be applicable to the paradigms currently being developed by management researchers. Unfortunately, those developing programs of research on teams in the management literature are often unaware of developments in the military sector. All facets of military TDM making teams will not necessarily relate to all aspects of management teams. However, some facets may indeed be relevant to the management context. Awareness of ongoing military research will enable management researchers to decide whether research issues are relevant to their paradigms. Organizations are encouraged to capitalize on possibilities for technology transfer from the military research community, with regard to optimal utilization of decision making teams.

The purpose of the paper is to describe several programs of research in the area of tactical decision making teams, sponsored by or conducted within the military, and to show the relevance of this research for management research focused on teams. Specifically, this review will focus on methodological and substantive aspects of several programs of research. Each of those programs will be described methodologically in terms of (a) the paradigm employed, (b) the experimental stimuli used, and (c) the manipulable measures of team process and effectiveness. Each of these programs will also be described substantively with regard to the major hypotheses of test findings from these lines of research related to (a) team composition, (b) training of team decision making, and/or (c) development of team decision enhancement technology (decision aids). We will begin by describing several major research programs now in force.

Table 1

Individual-level characteristics and team effectiveness addressed in six academic journals from 1987 through 1992*

INDIVIDUAL CHARACTERISTICS	AUTHORS
Ability/experience/expertise	Libby, Trotman, & Zimmer, 1987 Watson, Michaelsen, & Sharp, 1991
Affect/personality/motivation	George, 1990; 1992 Tang, Tollison, & Whiteside, 1987
Heuristics/Information processing/ cognitive bias	Abualsamh, Carlin & McDaniel, 1990 Baron, Beattie, & Hershey, 1988 Kameda & Davis, 1990 Magjuka & Baldwin, 1991 Mitchell & Silver, 1990 Sterman, 1989 Thomas & McDaniel, 1990 Whyte, 1989

* The following journals were searched, from January 1987 through December 1992: Academy of Management Journal, Journal of Applied Psychology, Personnel Psychology, Organizational Behavior and Human Decision Processes, Administrative Science Quarterly, and Academy of Management Review.

Table 2

Social and team-level characteristics and team effectiveness addressed in six academic journals from 1987 through 1992*

SOCIAL AND TEAM-LEVEL CHARACTERISTICS	AUTHORS
Demographic/cultural diversity	Cox, Lobel, & McLeod, 1991 Hambrick & Mason, 1984 Jackson, Brett, Sessa, Cooper, Julin, & Peyronnin, 1991 Mascarenhas, 1989 Michel & Hambrick, 1992 O'Reilly, Caldwell, & Barnett, 1989 Wiersema & Bantel, 1992
Dyadic interactions within groups	Crouch, 1987 Crouch & Yetton, 1988 Seers, 1989
Familiarity	Eisenhardt & Schoonhoven, 1990 Goodman & Leyden, 1991
Functional overlap	Magjuka & Baldwin, 1991 Michel & Hambrick, 1992
Power/Managerial discretion	Finkelstein, 1992 Finkelstein & Hambrick, 1990
Social interaction/interdependence	Crouch & Yetton, 1988 Larson & Christensen, in press Murnighan & Conlon, 1991 Ono & Davis, 1988 Sniezek, May, & Sawyer, 1990
Social decision making	Bottger & Yetton, 1988 Crott, Szilvas, & Zuber, 1991 Vollrath, Sheppard, Hinsz, & Davis, 1989 Whyte, 1989
Social loafing	Price, 1987
Team size	Eisenhardt & Schoonhoven, 1990 Gallupe, Dennis, Cooper, Valacich, Bastianutti, & Nanamaker, 1992

* The following journals were searched, from January 1987 through December 1992: Academy of Management Journal, Journal of Applied Psychology, Personnel Psychology, Organizational Behavior and Human Decision Processes, Administrative Science Quarterly, and Academy of Management Review.

Table 3

Situational characteristics and team effectiveness addressed in six academic journals from 1987 through 1992*

SITUATIONAL CHARACTERISTICS	AUTHORS
Anonymity	Price, 1987
Autonomy	Cordery, Mueller, & Smith, 1991 Manz & Sims, 1987 Tang, Tollison, & Whiteside, 1987
Decision support systems	Sainfort, Gustafson, Bosworth, & Hawkins, 1990
Information uncertainty/threat/stress	Argote, Turner, & Fichman, 1989 Driskell & Salas, 1991 Sugiman & Misumi, 1988
Organizational context	David, Pearce, & Randolph, 1989
Task characteristics	David, Pearce, & Randolph, 1989 George, 1992

* The following journals were searched, from January 1987 through December 1992: Academy of Management Journal, Journal of Applied Psychology, Personnel Psychology, Organizational Behavior and Human Decision Processes, Administrative Science Quarterly, and Academy of Management Review.

Ongoing Military Research on Teams in the United States

Several streams of research related to team effectiveness are being sponsored by organizations within the Department of Defense. The U.S. Navy directs research through organizations such as the Naval Command, Control, and Ocean Surveillance Center for Research, Development, Test and Evaluation (NRAD), the Office of Naval Technology (ONT), and the Naval Training Systems Center (NTSC). U.S. Air Force research is directed through organizations such as the Air Force Office of Scientific Research (AFOSR) and the Air Force Human Systems Center (HSC). U.S. Army research is directed through agencies such as the Army Research Institute for the Behavioral and Social Sciences (ARI). Additional organizations within each service (i.e. military academies and human resource-related operational organizations such as the Military Personnel Center) also perform independent research in human resource issues. Research is performed by military researchers at military sites, through private research companies, and by faculty at academic institutions. In addition, programs of research are often accomplished through coordinating efforts among the service organizations.

This report investigates streams of research related to team effectiveness that is performed primarily by military researchers. The work of military researchers may be less familiar to the reader, as avenues of communication for military researchers include military technical reports and military conferences, as well as academic journals. In addition, as technical reports are published in advance of academic journal articles, communication to the academic community is somewhat delayed. The purpose of this report is to enable the reader to be more aware of the scope and issues relevant to team research currently performed by military researchers.

Team decision making technology: Development of computer-assisted team decision making aids.

The Naval Command, Control, and Ocean Surveillance Center for Research, Development, Test and Evaluation (NRAD) and the Air Force Systems Center sponsor research in team decision making, with a focus on development of computer software to assist in effective team tactical decision making. Computer-assisted decision software aids information processing and decision making through effective processing and display of pertinent information. These aids typically are based in networked computers, processing information received from outside to central decision makers. Displays located around the room provide updated information.

Much of previous research on C3 decision aids has focused on the individual decision maker. Information complexity and flow were analyzed with regard to the workload imposed on the decision maker (Duffy, 1990). As a result, current technology allows rapid prototyping of an individual decision scenario (Henry & Patterson, 1990). This software, Operability Assessment System for Integrated Simultaneous Engineering (OASIS) was developed by the Air Force to enable the configuration of a touch screen computer to simulate various displays which might be faced by a decision maker. For example, the system may simulate the displays faced by an individual tracking radar information. Of most interest to the researcher is a second computer which is networked to the display simulator. While the decision maker performs his or her task, the second computer analyzes the workload within the task, with regard to perceptual, auditory, tactile, and cognitive demands of the decision making task. Not included in the human operator models are the individual and social factors related to effective decision performance as these models have not yet been developed.

A new twist to the workload paradigm is a focus on the whole team as the decision makers (Duffy, in press) rather than the individual decision maker. The team is seen as the basis for information processing and distributed decision making. Duffy discusses the team decision making process from an information processing perspective, with stages of attention/perception, acquisition, encoding, storage, retrieval, and judgment. Within these stages, team decision biases are outlined as comprised of three types of errors: (a) informational - misinterpretation of content; (b) normative - resulting from affiliative influences; and (c) structural - resulting from organizational processes and context. This systems perspective of team decision making is used to simulate and analyze the workload of team decision making (Duffy, personal communication), to enhance the design of decision aid systems and distribution of team member workload.

While technology can serve to identify and redistribute workload demands, decision aid researchers are also working to identify workload characteristics and their effects on decision making effectiveness. A comprehensive longitudinal study of C3 decision making is currently being sponsored by NRAD to identify workload characteristics and their effects (Feher, 1990). Empirical data from actual naval fleet maneuvers are used to construct simulation experiments, which drive laboratory experiments for causal analysis investigations. Currently being investigated are the effects of information delay, information degradation, and information density.

The delineation of individual and team mental models is an integral part of the decision aid research. The "mental model" refers to the cognitive representation each team member has of the team scenario, including the team goal, task strategies, and current status of performance. The higher the overlap in team member mental models, the higher is the expectation that team members have accurate representations regarding the needs of the other team members. This concept is reflected in a current C3 theory described by Crumley and Sherman (1990) that states that each commander has an internal model of his/her warfare area, called the principal expert model. Each commander must also have concepts about the principal expert models of commanders with whom he or she interacts, called military expert models. Currently, efforts are underway to map the cognitive network of expert versus novice tactical decision makers (Gwynne & Feher, 1990). Much of the work in designing C3 systems is focused on enhancement of the commander's mental model.

Reviews of military decision making in action has established that operational decision making can often differ from the prescribed doctrine (Feher, 1990), with regard to communication patterns and variability in the interpretation of incoming information. The sources of decision variability are under investigation. Of special interest in this effort are factors such as information degradation, delay, and density.

Feher (1990) outlines five categories of factors influencing information processing and decision making effectiveness of the Naval Warfare Commander (WC). First, the organizational context, including the composition, roles, and relationships of the decision making team, will affect information flow, decision making workload, coordination demand, and perceptions of current performance. This includes the knowledge, skills, and abilities of team members as well as functional concerns such as distribution of decision making responsibilities. A second area of study investigates the effect of information characteristics, including density, consistency, ambiguity, conflict, delay, and degradation. At this time it is not known to what extent each characteristic can affect performance or the interactions that may exist. A third category of variables are the task characteristics, such as tempo, complexity, and tactical aspects to the tasks, which overlaps somewhat with information characteristics. Both present variations of workload type and demand upon the decision maker. A fourth category includes individual characteristics and cognitive mechanisms, such as individual differences in initial expectations, expertise, and tactical decision making style. The last category is that of team characteristics which mediate information processing and problem solving effectiveness, such as communication and coordination strategies. Decision making in operational battle training exercises is reviewed and compared to the prescribed decisions identified for the battle scenario. Discrepancies between prescribed and actual decisions form the basis for hypothesis generation. These hypotheses are then further investigated under laboratory conditions.

Additional efforts in decision aid research include the definition of communication structure and assignment of tasks to computer and human members (Lehner, 1991; Lehner, Nallappa, O'Conner, Saks, & Mullin, 1991). Related to communication structures is the effect of various computer-mediated communications compared to face-to-face communications among team members. Advances in telecommunications drive investigation of effects of computer-mediated communications. Weisband, Linville, Liebhaber, Obermayer, & Fallesen (1988) review findings with regard to computer-mediated communications and distributed decision making. Differences in performance among communication channels and decision aids were hypothesized to arise from their effect on psychological and social factors such as feedback, group stability, team coordination/cooperation, status within groups, disparate ability, team size, work structure/distribution, communication structure, and group planning. Reder and Conklin (1988) also describe theory and empirical findings with regard to the effect of communication channel on distributed communication and decision making tasks. Empirical findings described in their report suggest effects of communication channels depend on the (a) nature of the collective task (tasks high in conflict or personal involvement exhibited channel effects), (b) extent of familiarity and solidarity among team members, and (c) members' familiarity with the communication channel.

Also under study are organizational contextual factors expected to affect distributed decision making systems. Models and algorithms are built to more fully capture the dynamics of distributed decision making at the organizational level (Sastry, Baker, Clare, Fehling, Lippitz, & Richardson, 1990), based on organization theory concepts, rather than simplistic computational optimization. Carley (1991) investigated organizational information access structures (segregated, tripley redundant, and distributed) in a simulation study with regard to performance under crisis across levels of training. She found that optimal crisis configuration depends on the amount of training, such that dual-command hierarchies were effective when participants were fully trained, but team structures may be more effective when participants are not fully trained.

The interactions of the type of decision aid with individual and social characteristics need to be identified. Experts in judgment of team effectiveness provide guidelines necessary for realistic scenarios and evaluation of team judgments. For example, C3 control scientists provide normative and prescriptive models of C3 tactical decision making behavior. These experts provide the means by which organizational scientists can investigate and evaluate the impact of social and individual factors on effectiveness in team decision making. After all, engineers and C3 control scientists realize the "inevitable interaction of humans with computer-based decision support systems and decision aids" (Athans, 1986). Descriptive models of actual decision making behavior are needed for comparison to the prescriptive models that drive decision aid design.

Decision aid development is based on findings from basic research. Some additional issues of interest to the decision aid community include (a) differences in decision making effectiveness between co-located versus distributed (geographically or temporally) meetings, (b) differences between unaided team decision making and computer-assisted decision making, (c) differences between group and individual errors, (d) impact of team communication patterns, (e) the role of differential views of the problem and (f) selection and training of effective teams (Duffy, 1990).

To summarize, there are two perspectives from which organizations can approach military decision aid research. One is the consideration of issues by which the decision aid is developed. Decision aids for organizational decisions, such as human resource planning, are analogous to military decision aids, and development/ design considerations as described above are relevant for both. The other perspective is the consideration of basic research issues as considered by military and organizational scientists, such as individual differences, task and information characteristics, and organizational context. Military research from both perspectives should be relevant to current research by organizational scientists in the civilian academic community.

Command, Control, and Communication (C3) Materiel decision making: Tactical planning and distribution of supplies.

Operation Desert Storm exemplified the critical advantage gained from rapid and effective deployment of personnel and supplies. Command, control, and communication (C3) materiel decision making involves both a priori development of contingency plans and ongoing decision making during implementation. Both types of decision making are being investigated by scientists sponsored by the Army Research Institute. This section will provide an overview of some of these efforts, but should not be considered exhaustive.

The paradigm of research used by this research effort is also based on identification of mental models. Comparisons of expert versus novice decision makers suggest that experts have a different conceptualization of the problem and process information differently than do individuals with less expertise (Michel & Riedel, 1988). Serfaty and Michel (1990) describe the nature of expert tactical knowledge and sources of differences from novice tactical knowledge and problem solving strategy. These differences include expert emphasis or skill with regard to (a) processes of exploration and mental simulation as opposed to reliance on standardized rules, (b) lower perceived uncertainty due to proactive factfinding and reconstruction of missing variables, (c) tendency to seek information that disconfirms rather than confirms hypotheses, (d) use of war stories and dynamic mental imagery to store and retrieve information, (e) planning by a multiple inductive-deductive-inductive reasoning sequence, and (f) awareness of the limitations of their mental models (i.e. they know what they don't know). A thorough discussion of expert-novice issues and information-gathering strategies is provided by Kirschenbaum (1992).

In addition to the separate mental models of team members, a mental model is proposed which reflects the conceptualization of the team as a whole (Klein & Thordsen, 1990). The team mental model is similar to an individual mental model, and "attends" to information much the way an individual would observe and process information. However, the team mental model is a group-level phenomenon and is described with regard to the configuration and overlap of individual team member mental models. Klein and MacGregor (1988) provide an indepth review of methods to capture the knowledge and mental representations of expert decision makers. They recommend a critical decisions approach to knowledge elicitation, similar to the critical incidents technique for the identification of knowledge needed to perform a job. The authors developed a structured interview format to elicit the critical incidents within a decision making scenario.

The critical incident interview technique of Klein & McGregor (1988) was designed for the study of decision making in naturalistic environments, to identify the decision process and strategies used by experts in the field. Klein and MacGregor reviewed various approaches to knowledge elicitation, such as memory recall and recognition; close experiments, multidimensional scaling, protocol analysis, repertory grid, and regression techniques. The Critical Decision Method (CDM) was described as a form of protocol analysis and process tracing - that is, the identification and examination of what actually happens during decision making. A common strategy for process tracing is to have participants "think aloud" when making decisions. However, the CDM interview method, elicits information regarding decisions which were made in the past. For example, this technique was used to elicit information from fire ground commanders as to critical decisions made during firefighting (Klein, Calderwood, & Clinton-Cirocco, 1988).

Obviously, the think-aloud technique cannot be employed under conditions of rapid decision making under high stress. This trades the control inherent in on-line techniques with regard to memory, for the opportunity to probe decisions considered critical. Therefore, CDM offeres an alternative measurement technique for situations where the think-aloud technique is not feasible

Results from the CDM interview technique indicate that decision processes for high-stress rapid decisions do not follow the paradigm of logical decision analysis. Instead, support was found for recognition-primed decision making. The ability of experts appear to depend on the recognition of general prototypes developed through experience. Klein, Calderwood, and Clinton-Cirocco (1988) utilized the critical decisions approach to investigate the decision making strategies of Fire Ground Commanders to identify the decision making processes within a scenario loaded with critical decisions made under time pressure. They found no support for traditional analytical models of decision making. Instead, they proposed that under conditions of high expertise, stress, and time pressure, decision makers rely on recognitional matching of problem scenarios based on previous experience. Decision makers in these situations are thought to make an intuitive assessment of the problem, matching it with familiar scenarios from past experience. One option is then generated. If this option is not valid, then a second option is generated. The decision makers interviewed in their study did report considering more than one option at a time. This contrasts with literature results stating that effective high-speed strategic decision makers utilize more information and generate more alternatives (Eisenhardt, 1989). However, disregarding the difference in definitions of high speed (2 months was considered short in Eisenhardt's study of microcomputer company top management) and type of decision, the results may still be congruent with the concept of mental models and intuitive problem recognition: effective executives may have made "instant decisions" to collect certain kinds of information relevant to their scenario.

While the CDM method results in support for recognition-primed decision making, it is not known to what extent results are based on the method used to investigate the decision making process. The CDM method relies on memory, and can thus be distorted from the actual processes that occurred during decision making. Various approaches to the study of decision making should be utilized, in order to disentangle the method of study from the actual process being studied.

Constructs which have been investigated in experiments by ARI researchers include cognitive style and degree of expertise (Michel & Riedel, 1988). These constructs are expected to affect the pattern of information use based on differences in expert vs novice representations of the problem. Individual cognitive style was expected to be a function of previous experience with the task. Familiar tasks were expected to evoke concrete operational mode of information processing, using reasoning by analogy, while unfamiliar tasks should evoke formal analytical reasoning.

Michel & Riedel (1988) hypothesized that cognitive style was related to the pattern of information usage by participants: participants with a "global" perspective were expected to perceive the total undifferentiated perspective, and to use less detailed information. Preliminary experiments suggest that less experienced individuals used more specific information than experts.

Experimental stimuli consisted of decision aid technology which presents subjects with information on request. This system tracked the information requested by each participant. Information in a computerized data base provided "inputs" from various sources of C3 information. Criterion measures included performance time, gross search patterns, number of data elements viewed, level of detail used, functional area use, data category use, data element use, graphics data use, working file use, problem solution, and responses to a questionnaire. Preliminary results indicate expertise is related to decision processes such as number of data

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elements viewed and level of detail used (Michel & Riedel, 1988).

Another decision stimulus developed by the ARI group is a group problem solving exercise which enables measurement of both task outcome and group process variables (Lussier, 1990). This task presents experienced officers a resource allocation and planning problem which required group members to divide into subgroups to work on interdependent subproblems. The group as a whole began with a fixed amount of resources; their mission was to develop a 3-year plan which coordinates budget, training, and personnel decisions for effective training of some or all of 88 army units. Objective scoring scales in a behavioral anchored format were used by observers to rate the group on (a) getting organized, (b) information sharing, (c) decision making, (d) professionalism, and (e) leadership. Decisions are scored on the basis of criteria such as (a) which training devices are selected for purchase, (b) where the devices are located, and (c) wastage of resources due to poor coordination. Team products were highly interdependent, thus the total group score is not simply the sum of the quality of subgroup decisions.

ARI researchers are also working to identify task and process measures of effectiveness from an organizational perspective. Previous research and methodologies for the assessment of C3 organizational effectiveness were reviewed and evaluated (Crumley, 1989). Crumley provided a comprehensive description of the extent and nature of command and control research at the organizational level. Studies reviewed tested conceptual frameworks and measures of C3 organizational effectiveness. As an example, the author defined organizational competence using three concepts (a) reality testing: organizational capacity to test the reality of situations facing the organization; (b) adaptability: organizational capacity to solve problems arising from changing environmental demands with effective flexibility; and (c) integration: the maintenance of structure and function under stress, and a state of relations among subunits that ensures that coordination is maintained. In this study, seven organizational processes were hypothesized as relating to the three competencies. Processes included sensing, communicating information, feedback, decision making, communicating implementation, coping actions, and stabilizing. Measures of organizational competencies were based on content analyses of communications and related to measures of organizational effectiveness. Crumley and Sherman (1990) also reviewed literature on C3 models and theory, describing five basic types of models: (a) models which are implementational in intent, such as field manuals, (b) organizational models based on organizational or management theorists, (c) behavioral system models, (d) systems-oriented models, and (e) network based models. While none of the models were considered sufficient for prediction, the organizational or management theory perspective was considered more productive. Although these studies and reviews were not addressing tactical decision making per se, they underline the impact of organizational context on team decision making.

It is apparent that the identification of expert knowledge and representation of team decision making scenarios is quite promising for the measurement of team member ability and facilitation of training (Orasunu & Salas, in press). This cognitive approach to the representation of knowledge also facilitates the development of electronic decision aids (Hamill & Stewart, 1987). Further research is necessary for development of appropriate measures of team mental models and the overlap in mental models among team members. The concept of shared mental models has immediate implications for training, especially regarding the cross-training of team members. Klein and MacGregor (1988) also proposed that deliberate decision making is entirely different from high-speed decision making under stress, and that individuals differ in their suitability for each kind of decision.

TDM Team Effectiveness: Training Issues

The Naval Training Systems Center (NTSC) coordinates a multifaceted approach to research related to team training. The following issues were identified for study (Morgan & Salas, 1988): (a) teamwork learning processes, (b) quantitative performance standards for acquisition of teamwork skills, (c) measurement systems for assessment of team training and performance, (d) training methods relevant to team training, and (e) identification of "what teams really do" during performance and how behaviors change over time. Morgan and Salas (1988) described efforts to develop and standardize procedures for measuring team performance, and to identify skills related to team performance, team decision making, team training, and acquisition of teamwork skills. In addition, a historical perspective and review of military team research and related small group research was provided by Dyer (1984, 1986).

Of particular interest are issues related to the conceptualization of team decision making in real-world scenarios (Means, Salas, Cradall, & Jacobs, in press) and delineation of expert-novice differences. Team member mental representations of the decision task are under study. A team decision making task is hypothesized to contain several mental representations: (a) knowledge of the equipment used in the task; (b) knowledge of the task itself, including the information needed and how it is used; and (c) knowledge of his/her role and contribution to the task (Cannon-Bowers, Salas, & Converse, 1990). It is assumed that the higher the overlap in team member mental models, the more likely team members will have accurate representations regarding the needs of the other team members.

A current goal is the identification of the expert knowledge representations within a team task and identification of effective means of training this knowledge. It is expected that team effectiveness is a function of shared explanations and the compatibility of expectations generated from team members' mental models (Rouse, Cannon-Bowers, & Salas, 1992). Cannon-Bowers, Salas, and Converse (in press) provide an indepth description of the theory and application of mental models in team training and tactical decision making. An issue of interest is the fit between degree of overlap in team member mental models and type of decision task. Also discussed are issues of team member personality, attitudes, leader behavior, and implications for training.

Rouse et al. (1992) discussed issues and recent research in team tactical decision making. They outlined constructs of interest such as team communication and coordination, and provided a detailed description of mental models as the basis for expectations, explanations, and predictions. Four propositions were outlined for investigation of mental models of team performance. These propositions predicted team effectiveness would increase as (a) team member mental models are more accurate in expectations and explanations, (b) training is provided for development of appropriate expectations and (c) explanations, and (d) practice is increased.

One facet of the team mental model is the shared knowledge of team member functional roles. Baker, Salas, Cannon-Bowers, & Spector (1992) explored the effect of Inter-Positional Uncertainty (IPU) on team coordination and performance using undergraduate students and a flight simulator task. IPU was defined as a lack of clear, consistent understanding of the positional role responsibilities of the other team members. IPU was investigated within low and high workload conditions, and was found to have a detrimental effect on team coordination and performance in both conditions. Workload had most effect on team cooperation and communication.

Mathematical modeling technologies promise to provide new measures of team task effectiveness. These technologies may serve to delineate the process of interdependent team decisions. The interdependencies of team decision making require complex mathematics to simulate performance, even for relatively simple two-person tasks, particularly when ambiguity and time constraints must be incorporated in the model. Mathematical models enable a new perspective on performance through manipulations of variables which represent thresholds of decision behavior (Boettcher & Tenney, 1986).

A modeling technique currently investigated for application to team training is Petri nets, a graphical model which maps all decision/action points of each team member within a single representation (Coovert, Cannon-Bowers, & Salas, 1990; Coovert & Salas, 1990). Each transaction (i.e. information exchange, action) can be described or typified by probabilities and time latencies. The technology provides a detailed mapping of the behaviors of a single team, or a typical "effective" team. Potential applications include generation and assessment of alternative theories, development of process measures of effectiveness, input to systems engineers for diagnostic and feedback mechanisms, and input to training systems development. This area of research is pursued by the Naval Training Systems Center (NTSC) for the development of training and simulation of tactical decision making.

The Naval Training Systems Center also conducts research to identify critical team coordination behaviors and skills. Investigation of team maintenance processes is necessary for identification of necessary team skills and behaviors, and the specific procedures relevant for training. Data were analyzed from sources such as task analyses, simulator performance, and aircrew interviews to identify both skills and behaviors necessary for similar scenarios, for example helicopter flight requirements (Bowers, Morgan, & Salas, 1991). Once identified, the desired skills and behaviors were targeted for training in low and high-fidelity trainers.

A recent meta-analysis of team performance suggests that process measures such as group communication, coordination, and cohesiveness mediate the effect of group member ability and task characteristics on group performance (Freeberg & Rock, 1987). Training specialists need to know the effective coordination strategies under conditions of low and high workload. A particular issue reported by Bowers et al. addressed the relation of communication patterns under different levels of workload and noted conflicting results. Bowers found that while previous studies (Naylor & Briggs, 1965; Williges, Johnston, & Briggs, 1966) reported increased communication led to disrupted performance under high workload, more recent research has found otherwise. Kleinman & Serfaty (1989), using a resource allocation task, reported as task demands increased from low to moderate, communications increased. When the demands were further increased, communication was greatly reduced, but members continued to perform interdependent tasks. This phenomenon of implicit coordination is of great interest.

A promising approach to the explanation of implicit coordination is provided by cognitive scientists investigating the "mental models" of expert team members. Group communication behavior is also under study. Several researchers are investigating the nature of communications within team decision making. Utterances between team members of effective versus ineffective dyads and teams are compared for content and/or pattern differences. Foushee (1984) reported significant negative relationships between aircraft systems errors and acknowledgements of information provided by crewmembers. Other communication variables related to performance were number of commands, response uncertainty, expressions of frustration, expressions of anger, expressions of embarrassment, and rates of agreement.

Foushee (1984) hypothesized communication patterns to be influenced by the social norms of the aircrew situation. This effect was also observed by Kanki & Foushee (1989) in a simulator-based investigation of aircrew performance. While investigating the effect of fatigue on aircrew performance, they found that aircrews in the fatigued condition performed more effectively. This they attributed to the fact that aircrews in the fatigued condition worked together for several days prior to the simulator session. Previous team experience was hypothesized to have affected group process variables such that team communication was more effective. Communications within each team were examined for differences between the two conditions. Significant differences were found for total amount of communication and type of communication. These results provide reason to investigate more fully the relationships between (a) team previous experience and team effectiveness, (b) communication processes and team effectiveness, (c) team roles and norms with communication and team effectiveness, (d) individual ability and team composition with team communication and effectiveness, and (e) training interventions and team communication and effectiveness.

It is clear many research issues are salient with regard to enhancement of team communication and coordination processes. These include (a) the relationships of explicit and implicit coordination under various levels of workload and task type, (b) the identification of communication patterns related to effective coordination under different conditions, (c) the identification of individual and team characteristics that affect communication and coordination, and (d) the identification of effective training strategies to enhance team communication and coordination.

Investigators of communication and coordination processes face challenges in such basic research issues as construct definition (what is "coordination"), construct validation, taxonomic efforts (how to code and examine team member communications), and method (should each analysis be idiographic-- that is, particular to the specific task situation). At this initial phase of research, diversity in the approaches to investigating these issues is inevitable and necessary before a consensus as to constructs and methods can be achieved.

Team effectiveness under conditions of high stress: Tactical decision making in realistic simulations.

The Air Force Human Systems Center (HSC) currently investigates the effects of stress on team tactical decision making performance. Their Aircrew Evaluation Sustained Operations Performance (AESOP) facility presents tactical challenges using realistic scenarios in a high-fidelity command and control simulation. Scenarios include periods of increasing workload, threat, and time pressure, where crewmembers are faced with multiple demands for attention. The facility enables investigation of physiological response, communication patterns, individual differences, and group process variables. This research effort is focused on the effects of high stress on tactical decision making (Schiflett, Strome, Eddy, & Dalrymple, 1990).

Multiple measures of individual and team performance were developed for this research (Eddy, 1989). Eddy developed a four-tiered approach to the development of process and outcome measures of performance. At the first tier, measures of individual capability include measures of perceptual, cognitive, motor, personality, work experience, and on-task measures of response times on embedded tasks and number of omitted low-priority tasks. The second class of individual-level measures addressed individual performance in the scenario and described the extent to which the individual accomplished the specific contributions needed of his role, with regard to target detection, identification, interception, and destruction. Over 130 measures of this type were collected for each team member, most being in the form of latencies and errors. The third level of analysis included measures of system/team performance which reflect the degree to which the team as a whole accomplished tasks necessary for mission success. An example is the ratio of pairing interceptors with targets. Measures of system performance were those measures at the team level that do not vary according to specific mission (i.e. offensive versus defensive mission), an example being the accuracy and speed of data transfer to interceptor pilots. The fourth level of performance measurement was assessment of mission effectiveness. For example, if the mission is that of protection of a specific sector of air and ground space, measures of mission effectiveness would include number of enemy infiltrations, amount of fuel and weapons expended, and ratio of enemy lost to friendly assets.

It is apparent that while individual capabilities and performance can be high, and the team works as effectively as possible, the team may still fail in its mission, in conditions of high threat and high workload. The measures of team performance developed for AESOP research are primarily outcome measures. However, the research team is now investigating team process measures of effectiveness, to identify patterns of group interaction which lead to successful team outcome measures.

Process measures described behaviors enacted during the team task and included measures of team communications, member interaction, task analysis, decision strategies, and compliance with procedures (Eddy, 1989). These measures were examined for their relation to final outcomes measures. They are also used as dependent measures when investigating other factors which may affect performance, such as individual attributes and team composition.

Two general types of process measures were used: (a) task-oriented measures such as decision strategies and team workload measures and (b) measures related to the maintenance of group communication and cohesion. The AESOP facility allows maximum generalization to the field due to the close mapping of the simulator to actual wartime scenarios and tasks. Subjects must have indepth knowledge of specialized tasks and strategies and are usually active duty weapons directors. AESOP was developed under the sponsorship of the Office of Military Performance Assessment Technology for triservice research (Schiflett, Strome, Eddy, & Dalrymple, 1990).

A team approach to team research: Tactical Decision Making Under Stress (TADMUS).

Up to this point research has been described within each service sponsoring the research. However, there is a coordinating mechanism to military team research. The Tactical Decision Making Under Stress (TADMUS) project is a joint-service effort to delineate and coordinate military research projects in tactical decision making under stress. Participants include the Naval Training Systems Center, the Naval Ocean Systems Center, the Air Force Human Systems Division, and other military, industrial, and academic organizations. TADMUS includes five interrelated streams of research: (a) definition and measurement of critical decision tasks, (b) examination of stress effects on decision making, (c) development of decision support principles, (d) development of training and simulation principles, and (e) development of display principles (Cannon-Bowers, Salas, & Grossman, 1991). Cannon-Bowers et al describe issues, constructs, and theoretical frameworks under investigation, most of which have been discussed in this report. Additional issues being studied include measurement of stress, exposure to stress during training, diagnostic measures of team performance, controlled versus automatic cognitive processing, explanation-based reasoning, and display design.

Summary

Military research in team tactical decision making is generating a broad field of knowledge, based on coordinating efforts in several streams of research. An interdisciplinary joint-service approach coordinates a diverse array of issues, from basic research in group process and decision environments to the design and development of decision aids and training systems. Empirical studies have identified variables affecting performance within tactical decision making scenarios. General theories of team performance suggest individual and group characteristics expected to affect performance, and strategies for effective training. Frameworks for further investigation of team tactical decision making are in place. Clearly, not all of the knowledge generated by these programs of research are relevant to all studies of non-military teams. However, some of these research programs are relevant to studies of TDM in business and industry. Hopefully, this review will provide management researchers with enough background to investigate the relevancy themselves.

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