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ARL Insights From the Battle Command Re-engineering III Concept Experimentation Program

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Abstract

The Mounted Maneuver Battle Laboratory at Fort Knox, Kentucky, conducted the third battle command re-engineering experiment (BCR III), during the period of April 12 to April 30, 1999. This report describes the research efforts of the Human Research and Engineering (HRED) of the U.S. Army Research Laboratory (ARL) in support of BCR III. This research is a key element of the ARL 5-year science and technology objective (STO) IV.G.10: cognitive engineering of the digitized battlefield. For BCR III, ARL's efforts were centered on the virtual exercise in which a model future strike force variant organization with modular semi-automated forces (ModSAF)-based displays and advanced combat systems, performed battle command operations in order to gain a more robust understanding of the potential offered by these technological and organizational capabilities. Within the framework of the BCR III overarching issues, ARL's focal point was associated with the sub-issue question: *What is the impact of situational awareness certainty and its cognitive effect on decision making, information request, and staff dynamics?* This report cites the findings from the application of two ARL cognitive engineering-based research instruments, as well as observation-based insights and commanders' comments recorded during a focus group session held by ARL following the final after-action review. The two ARL instruments, the decision maker self-report profile (DMSRP) and the commander-centered decision environment inventory (C^2DEI) focused on the various cognitive processes and environmental complexities associated with battle command decision making experienced during BCR III.

ACKNOWLEDGMENTS

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EXECUTIVE SUMMARY

The Mounted Maneuver Battle Laboratory at Ft. Knox, Kentucky, conducted the third battle command re-engineering experiment (BCR III), during the period of April 12 to April 30, 1999. The purpose of the BCR experimental series is to examine the effects of advanced digitization in the form of modular semi-automated forces (ModSAF) and a conceptual multi-functional staff on the battle command processes of battle space information assimilation, visualization, communication, and decision making at brigade and below.

The goal of the U.S. Army Research Laboratory's (ARL's) support of the BCR series is to provide the Army with insights regarding the application of advanced information and display technologies to the distributed command decision-making process. This research is a key element of the ARL 5-year science and technology objective (STO) IV.G.10: cognitive engineering of the digitized battlefield. For BCR III, ARL's efforts were centered on the virtual exercise in which a model future strike force variant organization with ModSAF-based displays and advanced combat systems performed battle command operations in order to gain a more robust understanding of the potential offered by these technological and organizational capabilities. Within the framework of the BCR III overarching issues, ARL's focal point was associated with the sub-issue question: *What is the impact of situational awareness certainty and its cognitive effect on decision making, information request, and staff dynamics?* This report cites the findings from the application of two ARL cognitive engineering-based research instruments, as well as observation-based insights and commanders' comments recorded during a focus group session held by ARL following the final after-action review (AAR). The two ARL instruments, the decision-maker self-report profile (DMSRP) and the commander-centered decision environment inventory (C^2DEI), focused on various cognitive processes and environmental complexities associated with battle command decision making experienced during BCR III. Specifically. the DMSRP instrument is designed to identify the (a) types of individual mental processes and structures involved in the commander's sense making and critical event decision making; (b) critical features, cues, indicators, or patterns recognized and used by the decision maker during the decision event and the primary sources of these triggering features, cues, and indicators; (c) type of uncertainty that is experienced during the decision event and the strategies used to cope with the uncertainty; (d) type of information process activities used by the decision maker during the decision event; (e) decision maker's view of the level of workload experienced during a critical decision event; and (f) commander-decision maker's interaction with key tactical operations center (TOC) staff in information seeking and deliberations leading to and during a critical

decision event. The C^2DEI instrument gathers data regarding the assertion that mission, enemy, troops, terrain and weather, time available, and civilian considerations (METT-TC) dimensions represent important elements in the commander's decision-making process during the execution phase of combat operations. Ancillary C^2DEI foci included (a) assessing perceptions of the information technology (IT) available to the decision makers and ascertaining if such perceptions would vary according to decision "type" (i.e., major change versus minor adjustment to course of action [COA]), and (b) assessing the physical environment and impacts on the immediate decision.

The results of the DMSRP and C^2DEI instrument applications, as well as the general observation-based insights and focus group comments recorded during BCR III, are the subjects of this report. The report consists of four sections, the first two of which (the DMSRP results and the C^2DEI results) represent independent research investigations.

Summaries of Results

Section 1: Decision-Maker Self-Report Profile (DMSRP)

The DMSRP instrument, to be completed by the decision maker, is comprised of a narrative description of a critical decision event and 15 decision event-related cognitive descriptive components that chart the decision maker's mental processes associated with military decision making. The DMSRP survey data for 38 critical decision events identified by the unit commanders were collected during the BCR III experiment. Analysis highlights of the 38 surveys are presented below:

Decision Time Window

The time when the decision maker became aware of the initiating conditions to the time when he or she made the new response, COA, or adjustment decision was less than 30 minutes for each of the 38 decision events recorded. The average time to make a decision was 9 minutes, with a mean time of 8.6 minutes for "significant change" decisions and 9.2 minutes for "minor adjustment" decisions. No significant difference was found in terms of time window associated with decision type.

Decision Type

The DMSRP lists two options for decision type relative to the ongoing COA previously selected by the decision maker: (a) a "significant change to the ongoing COA" or

(b) a "minor adjustment to the ongoing COA." The specific definition of significant change or minor adjustment is left to the discretion of the individual decision maker, since the authors feel that each battlefield situation has complexities that cannot be pre-defined. Of the 38 command decisions recorded, 16 (42%) were considered to be a "significant change" to the ongoing COA, while the remainder were considered to be "minor adjustments" to the ongoing COA. No significant differences were found between the commander-deputy commander and the troop commanders in the decision type made.

Aspects of the Operations Order (OPORD) That Were Changed or Adjusted

The aspects of the OPORD that were changed or adjusted in the 38 decision events reported were mainly related to friendly scheme of maneuvers, fire support, and reconnaissance and surveillance.

Principal Causes for the Decision to Change or Adjust the Current COA

Five principal causes for the decision to change or adjust the COA were identified by the respondents: (a) Conducting decisive operations—react to unexpected threat or windows of opportunity, (b) re-orienting on projecting the force, (c) re-orienting on shaping the battle space, (d) re-interpreting the commander's intent, and (e) changing the Red Force projections or expectations. These responses suggest that when provided with the ModSAF type capabilities, the commanders at both squadron and troop levels were able to conduct decisive operations in reacting to unexpected threats or windows of opportunity, respond to changes by the Red Force, shape the battle space and re-orient on projecting the Blue Force when necessary. The squadron commander was able to quickly change his intent and communicate it when needed, and the troop commanders were able to receive, interpret, and implement the new intent relatively quickly.

The Cognitive Process Associated With the Critical Decision Event

Of the 38 surveys completed, 14 of the decision makers felt that the critical decision event suggested a simple match (i.e., "one immediately obvious response, COA change or adjustment" - Klein's recognition-primed decision [RPD] 1). Of the remaining 24 respondents who had not selected the simple match response, 5 indicated that only one option was considered and evaluated using explanatory reasoning and story telling, and 12 indicated that multiple options were considered and evaluated sequentially using explanatory reasoning. In no case did a decision maker consider the formal option of directing the staff to generate new options. Importantly, the remaining seven respondents reported their decision to "manage the situation due to uncertainty." All seven were troop commanders. This was an unexpected finding, given the level of situational awareness (SA) purported with the ModSAF display. This finding, however, could simply be a reflection of the single display at the troop level where the commanders (conducting unit or entity-level operations) experienced uncertainty because of the lack of a second display that would have assisted the cell in maintaining a comprehensive view of events unfolding across the entire squadron area of interest.

"Sources" Used for Gathering Information

Within the DMSRP, this component (sources used for gathering information) is associated with the "simple match" decision-making (RPD process 1) responses made in the previous component (cognitive process associated with the critical decision event). The purpose of the "sources" component is to identify the origin or sources of information that triggered the "simple match" type of recognition-primed decision making. Of the 38 decision events, 14 were identified by the commanders as involving "simple match" cognitive processes. The sources associated with these simple match processes varied by echelon, with a total of three reports by the senior commanders identifying the ModSAF display as a key source for battlefield information. Other principal "triggering" sources for the senior commanders included tactical communications between higher and lower echelons (two reports) and briefings (three reports). The troop commanders also used ModSAF displays (three reports), tactical communications, and briefings (two reports for each source) but additionally used live sensor feeds (eight reports), reconnaissance or "eyes on" (six reports), and staff discussions between higher and lower echelons (three reports) as principal sources that triggered the simple match process. Troop commanders' highlighting of these additional sources indicates the high priority placed upon real-time information as key to survival in a close battle area. The importance of this type of sources was also reinforced by the troop commanders in their comments recorded during the focus group discussions (see Section 4).

Types of Uncertainty Experienced and Coping Strategies Used

It was interesting to see the degree and type of uncertainty reported by the BCR III commanders, given the level of situation awareness inherent in the ModSAF simulation. While the decision makers experienced no uncertainty in 17 of the 38 decision events, a degree of uncertainty was associated with 21 events, with the commander-deputy commander and troop commanders experiencing uncertainty. Twelve of the 21 decision makers experienced uncertainty because of incomplete information about the situation. Another four declared to have had an incomplete understanding of the situation, even with complete information. Undifferentiated alternatives and confusion because of many meanings or interpretations accounted for the five remaining reasons for uncertainty. To cope with the uncertainty experienced, 8 of the 21 decision makers collected more information to reduce uncertainty, 14 made assumptions to address uncertainty, 5 formed understanding using plausible reasoning, 5 weighed pros and cons, 7 relied on intuition, and 1 used forestalling. Troop commanders experienced uncertainty twice as often as commander-deputy commanders during the critical decision events recorded, with a large percent of the uncertainty attributable to incomplete information about the situation. They attempted to reduce this lack of complete information by collecting more data or by making assumptions, reasoning, or simply ignoring the uncertainty and relying on intuition. With reference to the BRC III sub-issue question (*What is the impact of situational awareness certainty and its cognitive effect on decision making, information request and staff dynamics)*, implications are associated with the SA uncertainty reported. One likely effect was moderate to very high frustration, which, as noted in Section 3 (Observation-based Insights), might have been prompted by the feelings of lack of control and lack of timely commander's critical information requirements (CCIR) resolution experienced by the squadron commander and the micro-management pressures and the lack of "big picture" awareness experienced by the troop commanders. Thus, the uncertainty and frustration levels experienced were most likely significant contributors to the high "information request" levels observed and the "micro-management staff dynamics" also observed by ARL and reported by the troop commanders during BCR III.

Patterns of Commander-Staff Interaction

The patterns of commander-staff interaction associated with the critical decision events showed that no significant difference was found between the senior and junior commanders in their staff interaction during the critical decision event. Fifty percent of the decision makers made their decisions in isolation, while the remainder made their decisions in one of the following contexts: (a) within the context of a well-formed team; (b) they set the general decision framework but the staff completed the details; or (c) they delegated the decision to another staff member while monitoring the overall process.

Cognitive Workload

Several cognitive dimensions were assessed using the National Aeronautics and Space Administration task load index (NASA TLX) workload assessment metric. "Mental demand" varied across the decision events from very low to very high, while physical demand was rated very low to low. For "temporal demand," the ratings of low, moderate, and high demand were uniformly distributed across the 38 reported decision events. In terms of "performance," all the commanders felt that they were very successful in overcoming any problems associated with the critical event decisions, and the "effort expended" during most of the decision events was rated at moderate to low. The frustration level for all commanders was rated as very low or low during 19 (50%) of the critical decision events, with most of these ratings being made by the troop commanders. During the other 19 decision events, moderate to very high levels of frustration were experienced equally by both command groups. Possible explanations for these ratings might have been the feelings of lack of control and the lack of timely CCIR resolution experienced by the squadron commander, and the micro-management pressures and the lack of "big picture" awareness experienced by the troop commanders. These last two explanations were corroborated by ARL observations and by the troop commanders during the focus group discussions.

Information-Processing Activities

The final component of the DMSRP contained descriptors of 20 separate information-processing activities, and the respondents were asked to select and prioritize the three principal activities they used in support of the given decision event. The activities listed include those associated with monitoring processes, visualizations, and situation assessment methods, as well as various forms of reasoning and critical thinking skills. It was found that a significant difference existed between these two command groups in the type of information-processing activities used. The more senior decision makers (squadron commander [LTC] and deputy commander [MAJ]) used battlefield visualization and a combination of monitoring and vigilance activities to support decision making. While the junior troop commanders (Captains) used battlefield visualization as well, they also relied on pattern recognition and cause-and-effect reasoning as primary information-gathering and cognitive processing activities supporting decision making.

DMSRP Summary

The DMSRP instrument identified a number of patterns regarding usage of information from various sources and the perceived significance of selected information as a function of command echelon. Multi-dimensional scaling (MDS) solutions were obtained, which graphically portrayed how individuals link information in the process of situation assessment and decision making (see Figures 2 and 3 in main body text). The commander-deputy commander group focused on operational indicators that were keyed to aspects of battlefield shaping and decisive engagements. By contrast, the troop commanders' group placed more emphasis on information of direct consequence to the unit- or entity-level fight. From these insights, the need for several conceptual improvements in the current ModSAF emerged, such as commander-tailored visualizations of relative force ratios of combat effectiveness, current and historic sensor coverage and future status, and enemy intent projections versus friendly force dispositions-response times. It is recommended that such improved capabilities be considered for future ModSAF-based technology thrusts.

Finally, it is felt that the results from the application of the DMSRP during BCR III have demonstrated the instrument's utility for providing structured diagnostic insights into the complex technology-supported military decision-making process and as such, is a key research product of ARL's cognitive engineering research program. Ensuing applications of the instrument within the BCR venue can serve to map the cognitive constituents of military decision making as supported by advanced technological capabilities. DMSRP-tracked changes to the cognitive decision-making processes, as a function of the technological and organizational capabilities modeled within the continuing BCR experimental framework, would serve the mounted maneuver battle laboratory (MMBL) as a guide to the objective future war fighter suite of human-centered decision aids and battlefield visualization tools.

Section 2: Commander-Centered Decision Environment Inventory (C^2DEI)

The results of the BCR III application of the C^2DEI instrument indicated that the use of METT-TC as indicators of environmental complexity in combat situations appears to have high degrees of face and external validity. Additionally, the BCR III investigation has provided replication of previous findings (Cook, Leedom, Grynovicki, & Golden, 1999) which suggest that commanders recognize and value the six fundamental dimensions represented by the military acronym METT-TC and that they are able to assess the relative significance of the dimensions and their level of current understanding for discrete decisions. Results from the BCR III study indicate that the significance and understanding of certain METT-TC dimensions varied according to decision "type" (i.e., a significant change versus a minor adjustment). Taken together, the results to date confirm that the dimensions of METT-TC capture significant indicators of battle space complexity and can provide a useful framework from which to efficiently organize, represent, and visualize salient dimensions of the battlefield during the military decision-making process (MDMP). Such representations and visualizations should be designed into future implementations of information technology (e.g., the Army battle command system [ABCS]) in support of command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR).

Section 3: Observation-Based Insights of the BCR III Operations

This section outlines key command and organizational processes observed during BCR III and within this context discusses technology-based shortcomings observed and provides potential areas for future ModSAF-based capability expansion. While moment-to-moment entity-level situation awareness (ModSAF-based single-vehicle icon) was high in BCR III, an emergent "big picture" schema or squadron area of operations (AO)-based common relevant picture (CRP) was wanting. Additionally, recurring patterns of command-centered CCIRs went unnoticed by the support staff (i.e., the enemy operations and effects officers). The key observation-based insights taken from the BCR III exercises are (a) the need for creating and maintaining "common and accurate" CRP graphics to synchronize mental models among key staff as the situation dynamically evolves; (b) the need to dynamically manage the capturing, fusion, monitoring, and displaying of recurring or evolving CCIR, without resorting to micro-management; and (c) the tendency of ModSAF-based capabilities to promote a false sense of control as well as frustration. The tendency for advanced display-aided higher level commanders to become frustrated with apparent inaction on the part of lower level commanders and to subsequently attempt to micro-manage the battle is a practice that has been predicted with the coming of increased SA capabilities. In many instances, the squadron commander and key staff fought the battle from the ModSAF screens set to visualize the battle at the individual entity level. With this level of visualization, "time from order to engage a given element to time targets began to appear as killed" or "time from order to move to time entity icons started to move" appeared agonizingly slow. As the entity-level visualization prompted the reaction to expect almost immediate gratification, the virtual action seemed in slow motion rather than the expected nearly instantaneous action. This perceived "lack of response" subsequently prompted the flow of nearly constant queries and directions to the troop commanders over the command net. The result was that the commander (and staff) gave a rolling series of detailed directions to lower echelons (i.e., instructing the troop commanders about which specific entity target to engage, when and with what; when and where to move, or asking if a given entity was receiving attention, if a given order had been executed yet, why a given entity had not yet moved or why some directive had not been implemented). Such micro-management-centered staff dynamics could greatly increase the cognitive workload, frustration, and stress levels of the lower level commanders in the heat of battle. ARL therefore suggests that the ModSAF display be limited to two levels and that future BCR experiments play more realistic interactions between the battalion-squadron and higher echelons, as such interactions might tend to focus the battalion commander's attention away from the entity-level display details and more on "big picture" issues.

As a related insight, the squadron commander's nearly continuous radio net discussions with the troop commanders suggest that regardless of the level of SA (i.e., even to entity-level detail), both face-to-face and net-based verbal dialog will be sought to facilitate reconciliation of perspectives and affect mental model correspondence both horizontally and vertically across the battle command for effective situation assessment and decision making.

Section 4: Focus Group—Troop Commander Insights

As part of the ARL data collection efforts for BCR III, troop commanders were assembled immediately after the final AAR for the purpose of conducting focused discussions covering the technological and organizational structures employed. As a group, troop commanders were asked what they liked and disliked about the ModSAF technology, what changes were evident in operating as a digitally supported organization, and the implications of these changes and their general insights regarding the command process. Finally, if they could make one change, what would it be? A summary of the troop commander responses is presented in Section 4, which corroborates some of the ARL observation-based insights, including the need for a CRP-type graphic for SA maintenance, automation-based fusion of CCIR, and a propensity for micro-management staff dynamics.

ARL INSIGHTS FROM THE BATTLE COMMAND RE-ENGINEERING III CONCEPT EXPERIMENTATION PROGRAM

INTRODUCTION

This report presents (in four sections) the results of the U.S. Army Research Laboratory's (ARL's) data collection efforts for the Mounted Maneuver Battle Laboratory (MMBL) battle command re-engineering experiment (BCR III). The report consists of four sections, the first two of which (the decision-maker self-report profile [DMSRP] results and the commander-centered decision environment inventory [C^2DEI] results) represent independent research investigations. Within the framework of the BCR III overarching issues, ARL's collection focal point was associated with the sub-issue question: *What is the impact of situational awareness certainty and its cognitive effect on decision making, information request, and staff dynamics?* This report cites the findings from the ARL application of two cognitive engineering-based research instruments, as well as observation-based insights and commanders' comments recorded during a focus group session held by ARL following the final after-action review (AAR). The two ARL instruments (the DMSRP and the C^2DEI) focus on various cognitive processes and environmental complexities associated with battle command decision making. The first two sections (the DMSRP results and the C^2DEI results) represent independent research investigations. This research is a key element of the ARL 5-year science and technology objective (STO) IV.G.10: cognitive engineering of the digitized battlefield. The objective of the STO is to assess the body of knowledge concerning the human cognitive processes associated with military decision making at the individual, team, and organizational levels and to gather additional corroborative information from observations and data collection during U.S. Army simulations and field experimentation such as the BCR series.

Results of this STO-based research are intended to be systematically applied to the design of future Army digital information systems, and the findings are offered to support the goals and objectives of the continuing BCR experimental program. This input is important since cognitive engineering influences system design, based on cognitive research findings regarding human mental processing requirements rather than on information technology-driven requirements. This difference is critical since the human interface is where the Army's evolving decision aid technology has the greatest opportunity to support the future commander's decision-making processes. It is becoming increasingly evident that the Army's design and fielding of advanced digital information systems technology must be based on a thorough understanding of the underlying cognitive processes associated with combined arms battle space command and control. This is the primary focus of the STO and ARL's BCR support efforts.

Overview

The MMBL at Ft. Knox, Kentucky, conducted the third BCR experiment (BCR III), during the period of April 12 to April 30, 1999. The purpose of the BCR experimental series is to examine the effects of advanced digitization in the form of modular semi-automated forces (ModSAF) and a conceptual multi-functional staff on the battle command processes of battle space information assimilation, visualization, communication, and decision making at brigade and below. Specifically, ModSAF provides a technological analog of the Army's future objective battlefield visualization system with real-time ground truth-based situational awareness (SA) of key mission, enemy, troops, terrain and weather, time available and civilian considerations (METT-TC) battlefield dimensions. This ModSAF-based SA is meant to provide the commander with the correct information, at the correct time, and in the correct intuitive format with the proper perspective for effective decision making. Equally important, the concept of the technologically facilitated multi-functional battalion staff is being examined in light of the new functions, tasks, and skill capabilities and the training challenges inherent within the re-engineered tactical operations center (TOC) initiative. Finally, the enhancement of the battalion's organic sensor and indirect fire capabilities is being studied as they link with the ModSAF-based SA to redefine the combat effectiveness of strike force-like battalion and below command and control operations.

The Human Research and Engineering Directorate of ARL provided an observer-data collection team to support the BCR III experiment. The ARL team watched the command group from the 2nd squadron of the 2nd Armored Cavalry Regiment (ACR) execute critical battalion and company-level elements of battle command during the planning and execution phases of the 9-day experiment. At the completion of each day's activities, ARL administered the DMSRP and the C^2DEI instruments, which focused on capturing the cognitive processes, and METT-TC-based complexities associated with critical decision events that occurred during that day. The DMSRP instrument is designed to identify the (a) types of individual mental processes and structures involved in the commander's sense making and critical event decision making; (b) critical features, cues, indicators, or patterns recognized and used by the decision maker during the decision event and the primary sources of these triggering features, cues, and indicators; (c) type of uncertainty that is experienced during the decision event and the strategies used to cope with the uncertainty; (d) type of information process activities used by the decision maker during the decision event; (e) the decision maker's view of the level of workload experienced during a critical decision event; and (f) commander-decision maker's interaction with key TOC staff in information seeking and deliberations leading to and during a critical decision event.

The C^2DEI instrument gathers data regarding the assertion that METT-TC dimensions represent important elements in the commander's decision-making process during the execution phase of combat operations. Ancillary C^2DEI foci included (a) assessing perceptions of the information technology (IT) available to the decision makers and ascertaining if such perceptions would vary according to decision "type" (i.e., major change versus minor adjustment to COA), and (b) assessing the physical environment and impacts on the immediate decision. The results of the DMSRP and C^2DEI instrument applications, as well as the general observation-based insights and focus group comments recorded during BCR III, are the subjects of this report.

Methodology

Before the start of the exercise, the ARL team briefed the squadron commander and his key staff about the objectives of the ARL effort within the BCR III experiment and briefly explained the combined DMSRP-C^2DEI instruments to familiarize the target audience with the instrument content and the research basis for their development. Subsequently, nine scenario trials (three movement to engagement, three defense, and three deliberate attack), lasting a maximum of 5 hours, were observed and assessed by the ARL team. Scenario observations focused on squadron-troop-level decision-making processes from the individual decision maker with supporting staff interaction perspective. The method of administering the combined DMSRP-C^2DEI instrument to the decision makers was via an automated computer-based data collection process developed by ARL. For a critical decision event previously identified, the decision maker proceeded to document within the computer-based instruments, the various cognitive processes that were felt to have been used during the selected critical decision event (the DMSRP) and the perceived significance and level of understanding of METT-TC dimensions as representations of environmental complexity. This automated cognitive profiling process immediately followed the day's trial and normally took approximately 8 to 10 minutes to complete.

Participants

Experiment participants were eight experienced company and field grade officers permanently assigned to the 2nd squadron of the 2nd ACR from Ft. Polk, Louisiana. The commander and his staff were representative of similar regular Army battalion- or company-level units in terms of grade distribution (e.g., E-2 to E-9 and 0-1 to 0-5) and experience.

Experimental Equipment and Terrain: Friendly Forces

As shown in Figure 1, the fighting unit examined in the BCR III experiment was an experimental battalion task force command group equipped with future battle commander's displays.

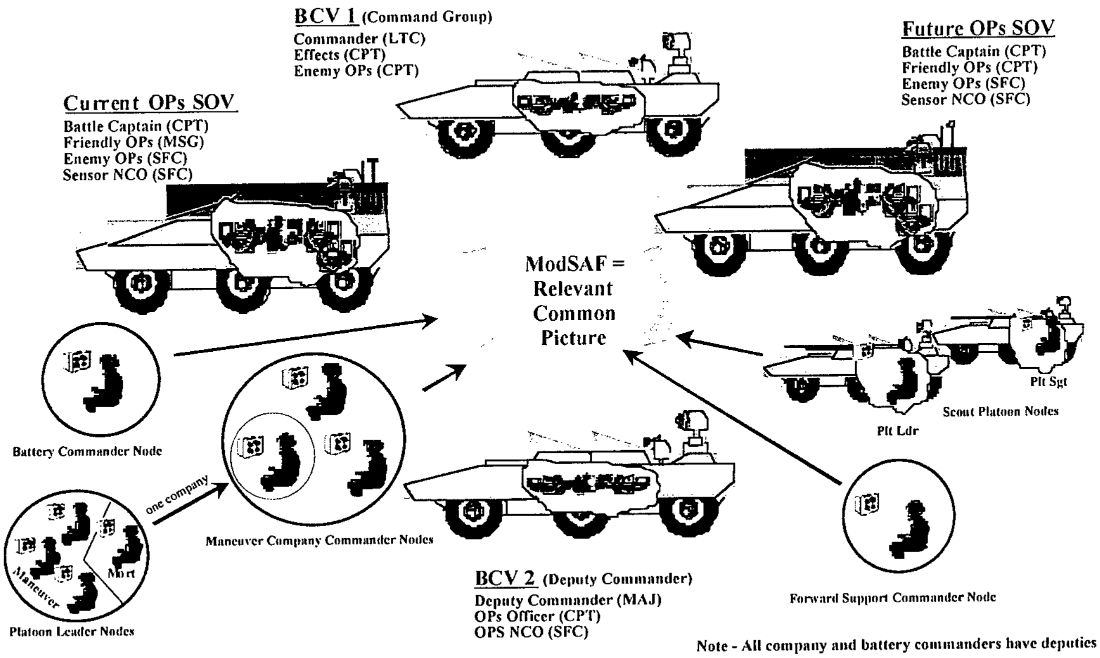


Figure 1. Re-engineered task force command group.

This experimental staff organization represented an attempt to streamline and consolidate certain staff functions. Figure 1 shows the command staff positions and their respective placement. The enemy operations and effects officers were collocated with the squadron commander. The inclusion of an effects officer was initiated during BCR II and was maintained in BCR III to provide the battle commander with assistance in shaping the battle space. The deputy commander was collocated with his operations officer and the operations noncommissioned officer (NCO), and the remaining two vehicle mock-ups contained the current operations and the future operations cells, respectively. Each vehicle mock-up was equipped with the advanced ModSAF system that provided statistical tools to perform entity-level battle damage assessment (BDA); a "calculate" function to summarize squadron information for size, location, activity, number, time and date (SLANT) reports and status; and multiple screen displays for viewing white board conferences and unmanned aerial vehicle (UAV) sensor images and for consolidating reports and presenting the terrain-based sensor-fed friendly and enemy battlefield information down to the single-vehicle (entity) level. In addition, the squadron was supported by an artillery battery commander (0-3), a forward support commander, a scout platoon leader (0-2), and three troop commanders (0-3). Employing future strike force 2010 technology, the virtual ModSAF unit was armed with advanced fighting vehicles, advanced sensors (national satellite coverage and four advanced scout vehicles and four reconnaissance, surveillance, and target acquisition [RSTA] systems with two organic UAVs), and robust long-range fires in the form of four advanced fire support systems (AFSS) systems with eight 120-mm rounds, four "missile in a box" vehicle systems with 120-mm precision guided missiles (PGMs), nine high mobility artillery rocket system (HIMARS) and six non-line-of-sight (NLOS) vehicle platforms, each with 24 Helfire and 6 chemical (CKEM) missiles.

Threat Forces

Threat forces consisted of a future concept regiment-sized heavy-light maneuver group containing three motorized rifle battalions (BMP-3 and BTR-80A), one tank battalion (T-90), and an air assault (light) infantry battalion. The primary threat weapons platforms were T-90 main battle tanks with 125-mm main gun and AT-8 (Songster) missiles, BMP3 vehicles with 100-mm guns and AT-6 (Spandrel) missiles, the BTR-80 with AT-7 antitank missiles, the 2S19 152-mm self-propelled howitzer, and the BM-21 multiple rocket launcher.

Virtual Terrain

The BCR III virtual ModSAF-based experiment used a German terrain database (i.e., region surrounding Grafenwoehr and Hohenfels). All simulated missions were conducted during daylight hours and were approximately 4 to 5 hours in duration.

DATA ANALYSIS, RESULTS, AND INSIGHTS

The following four sections cite findings from the ARL application of two cognitive engineering-based research instruments, the DMSRP (Section 1) and the C^2DEI (Section 2), observation-based insights (Section 3), and commander comments recorded during a focus group session held by ARL (Section 4).

SECTION 1: OVERVIEW OF THE DMSRP

The decision-maker self-report profile (DMSRP) is a data collection instrument designed to facilitate recording key cognitive elements related to critical decision events during U.S. Army experiments and exercises (Golden, in press). The DMSRP was designed as the data collection complement to an ARL cognitive engineering model entitled the initial descriptive model (IDM) of the execution decision cycle. ARL's original IDM was first published in a technical report entitled "Description of Brigade C2 Decision Process" (Adelman, Leedom, Murphy, & Killam, 1998). The IDM was classified as an integrative descriptive model of command decision making, since it attempts to describe how commanders think during battle management. The model is an integration of four recent theories about decision making from the cognitive science literature. The four theories are (a) Klein's (1993, 1997) recognition-primed decision (RPD) model, (b) Rouse and Valusek's (1993) decision model, (c) Beach's (1990, 1993) image theory, and (d) Lipshitz and Strauss's (1997) uncertainty model. The appropriateness of selected sub-models comprising the IDM were initially assessed by ARL through observations of key Army war-fighting exercises (AWEs). As expected, these initial field assessment efforts identified and documented significant deviations in real-world practice from the published military decision-making process (MDMP) doctrine. What ARL observed was the adaptive, heuristic nature of combat decision making, which appeared quite different from the rigid step-wise sequences outlined in the doctrine-driven MDMP. These deviations provided further support for ARL's selection of the four naturalistic decision-making theories and frameworks, which had been integrated into the IDM. Mapping the various cognitive processes in the IDM model, the DMSRP instrument is completed by the decision maker as a self-report of his or her cognitive processes used during execution-phase critical decision events. This was projected to be an effective method of validating and refining the descriptive processes of the original IDM. Collectively, the DMSRP component responses provide insights into the processes related to human cognition, as they appear to function in real-world, time-stressed, ambiguous environments of military decision making.

With ARL's primary focus being the BCR III sub-issue question, *What is the impact of situational awareness certainty and its cognitive effect on decision making, information request, and staff dynamics?,* the rationale for the DMSRP application was to collect information about the cognitive elements associated with critical decision event data from decision makers at different echelons (i.e., battalion, company). This application, together with other ARL data collection efforts, was designed to develop insights regarding (a) the degree of mental model consistency or commonality among commanders; (b) variability of the decision maker's information requirements over time, echelon, and battlefield situation; and (c) the degree of situational awareness certainty at various echelons and its effect on decision making, information seeking, and associated command-staff dynamics.

DMSRP Composition

The DMSRP has one section for providing a narrative description of the critical decision event and 15 event-associated components that chart the cognitive processes associated with military decision making. Four of the primary components had two to four sub-components that provided additional details for that component. The amplifying section, primary components, and sub-components, as sequenced in the DMSRP, are shown in Table 1. Note that Components 13 through 15 were taken from ARL's original STO-based critical decision inventory (CDI) instrument developed by Leedom (1998).

Table 1

Component Sequence in the DMSRP

Item	DMSRP component
1.	Location of the decision maker (TOC or echelon)
2.	Description of the new response, COA, or adjustment decision
3.	Length of window for decision event
4.	Decision type: Significant change or minor adjustment to COA
5.	Part or aspect of operations order (OPORD) changed or adjusted
6.	If significant COA change
	a. Principal causes for COA change
7.	If minor COA adjustment
	a. Principal causes for COA adjustment
8.	Process associated with decision making
	a. One immediately obvious response
9.	Features or patterns in current situation triggering decision event
10.	Source of triggering features or patterns
	b. One option considered, mental simulation
	c. Multiple options considered, mental simulation
	d. Formal option generation by staff (single or multiple)
	e. Manage the situation
11.	Type of uncertainty experienced
12.	Uncertainty coping strategies
13.	Patterns of commander-staff interaction
14.	Decision maker's cognitive workload estimate
15.	Information-processing activities (20 separate activities)

Analytical Methodology—Weighted Multi-Dimensional Scaling (WMDS)

The DMSRP instrument attempts to chart the characteristics and concepts representing the cognitive processes associated with execution phase military decision making. A major challenge to the analysis of the DMSRP data was the development of a methodological approach to the analysis and classification of the DMSRP-based multivariate critical decision process variables. Key to this approach was the use of weighted multi-dimensional scaling to help visualize the self-reported cognitive processes as captured in the DMSRP. Psychologically, one can view the multi-dimensional space as a graphic depiction of the decision maker's mental model (Torgerson, 1952; Converse & Kahler, 1992). With the use of multi-dimensional scaling techniques, objective scales of ranked order attributes, as reported by the subject decision makers, are constructed. These scales are subsequently mapped to two-dimensional characteristics associated with the decision maker such as experience (i.e., "less experienced" versus "more experienced"). The vectors of the information element space reflect similarities and dissimilarities in the data. The weighted Euclidean distance $D_{ijk} = [\Sigma w_{ka} (x_{ia} - x_{ja})^2]^{1/2}$, was used to account for individual differences in cognitive processes. The S-stress is used as a measure of fit:

$$\text{S-stress} = \left[l / m\Sigma_k \left(\frac{\|E_k\|}{\|T_k\|} \right) \right]^{1/2}$$

in which $\|E\|$ is the sum of all squared elements of the error matrix defined as $\|E\| = \|T_k - D^2\|$. Values of the S-stress statistic close to zero are an indication of a good fit. Analysis of the DMSRP results captured the commander-deputy commander and troop commanders' multivariate critical decision event patterns and preferences using a WMDS method and then confirmed these perceived patterns using discriminant analysis.

DMSRP Results

DMSRP survey forms for 38 critical decision events were collected during the BCR III experiment. This section provides the results of the WMDS and discriminant analysis process. The analysis results are presented in the DMSRP component order shown in Table 1. Note that the first two DMSRP components (location of the decision maker and decision event description) are not included in the data analysis effort reported here.

Time Window for the Decision

The time windows (i.e., Figure 1, "the time when the decision maker became aware of the initiating conditions to the time when he made the new response, COA, or adjustment decision") for the 38 decision events recorded were all less than 30 minutes. The average time to make a decision was 9 minutes, with a mean time of 8.6 minutes for "significant change" decisions and 9.2 minutes for "minor adjustment" decisions. The time range for "significant change" and "minor adjustment" decisions did overlap; thus, no significant difference in terms of time window was found associated with decision type (t = 0.28 sig. = .77).

Decision Type

As shown in Table 2, of the 38 DMSRP-based command decisions recorded during BCR III, 16 (42%) were considered to be a "significant change" to the ongoing COA (i.e., the new decision was considered a significant change to the currently implemented COA), whereas 22 (58%) were considered to be "minor adjustments" to the ongoing COA. Using discriminant analysis, no significant differences were found between the commander-deputy commander and the troop commanders in the decision type made (chi-square [x^2] = .116, sig. = .94).

Table 2

Decision Type

Decision type	No.	Percent
A significant change to ongoing COA	16	42
A minor adjustment to ongoing COA	22	58
Total	38	100

Aspects of OPORD Changed or Adjusted

As shown in Table 3, a large portion (41%) of the changes or adjustments made by the decision makers relative to the aspects within the current OPORD (for both significant change and minor adjustment decisions) was related to "friendly scheme of maneuver." Another 18% of the changes and adjustments were related to "logistics," with 16% to "fire support" and "reconnaissance and surveillance," respectively. Using discriminant analysis, no significant difference was found in the OPORD aspects changed or adjusted as a function of decision type (significant change versus minor adjustment decisions). Additionally, no significant differences were found between the squadron commander-deputy commander and the troop commanders in the OPORD aspects changed or adjusted ($x^2 = 31.3$, sig. = .59).

Table 3

Aspects of Currently Implemented OPORD Changed or Adjusted

Part of OPORD changed	No.	Percent
Friendly scheme of maneuver	31	41
Fire support	12	16
Reconnaissance and surveillance	12	16
Mobility or counter mobility	1	1
Engineers	0	0
Aviation	0	0
Air defense artillery (ADA)	3	4
Logistics	14	18
Other (specify)	3	4
Total	76[a]	100

[a]Respondents were permitted to select more than one aspect as changed or adjusted.

Principal Causes for Significant Change or Minor Adjustment to COA

This component of the DMSRP framed the decision by identifying the principal causes for the decision maker's significant change or minor adjustment to the current implemented COA. This permitted the identification of which elements of information available to the decision maker were critical in shaping his decision. As shown in Table 4, a total of 24 different response items (principal causes) are provided under this component of the DMSRP. Their selection was based upon review of Field Manuals (FM) 100-5, 101-5, and draft FM 100-40 (Department of the Army, 1993, 1997, in press).

The decision maker was requested to select the three principal causes for the decision to change or adjust the current COA and then to rank order the three causes selected with respect to each other. Using discriminant analysis, no significant differences were found between the squadron commander-deputy commander and the troop commanders in the causes for the decision to change or adjust the COA (Wilk's $\lambda = 0.89$, sig. = .68). However, of the 24 principal causes listed, five key causes were selected by the respondents in the 38 surveys

Table 4

Frequency Summary of the Principal Causes for Change or Adjustment to COA

Causes (in order of presentation)	No.	Percent
Change in rules of engagement	0	0
Re-orient on projecting the force	7	17
Re-orient on protecting the force	4	10
Re-orient on gaining information dominance	1	2
Re-orient on shaping the battle space	4	10
Re-orient on sustaining or transitioning to future operations	3	7
Changes relative to political, civilian population, contingency operations, operations other than war (OOTW), nuclear, biological, chemical (NBC) threat, terrorist threat	0	0
Conducting decisive operations: React to unexpected threat, exploit success or unexpected window of opportunity	6	14
Change in commander's intent	0	0
Change in mission directed from higher headquarters	2	5
Change in time table of commander's intent	0	0
Re-interpretation of commander's intent	3	7
Change to previously implemented goal(s)	1	2
Change in time table for achieving previously implemented goals	0	0
Reassessed projected outcome (end state) of previous goals	2	5
Adequacy of current plan to achieve goal(s) deemed less than optimum	1	2
Change in unit-essential tasks	0	0
Initiated pre-planned branch or sequel	0	0
Plan tactics or actions being implemented less than optimum to achieve goal(s)	2	4
Problem with concept of operation	0	0
Change in Blue Force projection	0	0
Change in Red Force projections or expectations	7	17
Change in the cues, indicators, or patterns used for pattern matching	0	0
Change in reading or interpreting the cues, patterns used	0	0
Total	43[a]	100

[a]Respondents were permitted to select more than one cause.

completed. The key causes were (a) re-orient on projecting the force, (b) change the Red Force projections or expectations, (c) conduct decisive operations-react to unexpected threat or windows of opportunity, (d) re-orient on shaping the battle space, (e) re-orient on protecting the force, and (f) re-interpret the commander's intent. It is interesting to note that this last cause, "changes in the Red Force projection and expectations," had several sub-components that permitted the respondent to indicate the aspect of the Red Force that had changed. Here, the decision makers identified force ratios, effects of enemy fires, and positional or movement factors as the key elements of change in the Red Force's projections or expectations that had initiated the critical decision event.

Doctrine, Training, Leader Development, Organizations, Materiel, and Soldiers (DTLOMS) Implications

The surrogate C4I system (ModSAF) with its entity-level "God's-eye" view, white board and common database system is purported to provide the commander and staff better than 90% situational awareness at every echelon, and the ready means to command and control assets. Provided this capability, the commanders at both squadron and troop levels were able to conduct decisive operations in reacting to unexpected threats or windows of opportunity, to respond to changes by the Red Force, shape the battle space, and re-orient on projecting the Blue Force when necessary. The squadron commander was able to quickly change his intent and communicate it when needed, and the troop commanders were able to receive, interpret, and implement the new intent relatively quickly.

Cognitive Process Associated with the Critical Decision Event

Component 8 of the DMSRP maps the IDM theory-based cognitive processes associated with decision making and requests the respondent to select the one process that best describes that used for the critical decision event in question. The results of this component analysis are presented in Table 5. By way of explanation, in mapping the ARL IDM, the DMSRP presents five distinct cognitive processes in this component of the instrument. The first three reflect Klein's RPD model in which Process 1 is the "simple match," wherein the situation is immediately recognized by the decision maker as typical, and an obvious COA is immediately recognized and implemented. Process 2 is "diagnose the situation" in which if the situation is not "typical," the decision maker enters into a feature-matching, story-building diagnostic single-option process until the situation is recognized as "typical" and the single COA is implemented. Process 3 is "evaluate courses of action," wherein mental context-specific evaluations (mental simulations) of multiple options are processes in sequence by the decision maker until one is selected for implementation. Of the remaining two processes presented under this component, Process 4 is the procedure directed by the commander and executed by the staff, wherein multiple COA options are formally developed and the final selection made by the commander. Process 5 is the complementing process of the Lipshitz and Strauss theory that addresses the issues of how decision makers conceptualize uncertainty and implement adaptive coping strategies to manage the situation due to uncertainty.

As shown in Table 5, of the 38 DMSRP surveys completed during BCR III, 14 of the decision makers felt that the critical decision event suggested a simple match (i.e., "one immediately obvious response, COA change or adjustment" - Klein's RPD 1). Of the remaining 24 respondents who had not selected the Simple Match response, 5 indicated that only one option (RPD 2) was considered and evaluated, using explanatory reasoning and story telling; 12 indicated that multiple options (RPD 3) were considered and evaluated sequentially, using explanatory reasoning; and the remaining 7 respondents reported deciding to "manage the situation due to uncertainty."

Table 5

Cognitive Process Associated With the Critical Decision Event

Cognitive process supporting decision making	Commander-deputy No.	Commander-deputy Percent	Troop commanders No.	Troop commanders Percent	No.	Percent
Simple match (RPD 1)	2	5	12	31	14	37
One option-mental simulation (RPD 2)	1	3	4	10	5	13
Multiple option-mental simulation (RPD 3)	6	15	6	15	12	31
Multiple option-formal staff process	0	0	0	0	0	0
Coping strategy-manage situation	0	0	7	19	7	19
Total	9	24	29	76	38	100

This latter finding, the relatively large number of respondents who reported managing the situation due to uncertainty, could be considered unexpected, given the level of situational awareness provided by the ModSAF display. All seven were troop commanders. As seen next, this finding is corroborated with the responses recorded for the ensuing DMSRP component concerning types of uncertainty experienced and coping strategies used. This uncertainty at the troop level could simply be a reflection of the issue associated with the single display in the cell where the commander (conducting unit or entity-level operations) might have experienced uncertainty because of the lack of a second display that would have assisted the cell in maintaining the "big picture" of events unfolding across the entire squadron area of interest (AOI).

"Sources" of Features or Patterns in the Current Situation that Triggered the "RPD 1-Simple Match" Process

Within the DMSRP, "sources of features or patterns in the current situation" is associated with the previous component that addressed the "cognitive process associated with the critical decision event" (see Table 5) with specific reference to the "simple match" decision making (RPD process 1). The purpose of the "sources" component is to identify the origin or source of information that triggered the "Simple Match" type of recognition primed decision making. As shown in Table 6, 17 sources (plus an "other" block) were listed under this component. The respondent could select as many as three sources if he or she so desired. As the DMSRP instrument was designed to be usable in a variety of tactical exercises and simulations, the list includes sources such as large screen displays, Army tactical command and control systems (ATCCS) information or displays and live sensor feeds. Since the BCR III played no ATCCS but had several ModSAF-based large screen displays, responses made to the large screen display item were considered to be referring to ModSAF.

As was shown in Table 5, 14 "Simple Match" process responses were reported, with the commander and deputy commander reporting one each and troop commanders reporting 12. As for the sources used which helped trigger the simple match processes, Table 6 shows a total of six reports (three senior commanders and three junior commanders [including one write-in under "other"]) listed the ModSAF display as a key source. Additional sources were used by the decision makers, but they varied by echelon. While the senior commanders reported the use of the synchronization matrix (one report) and the modified combined obstacle overlay (MCOO) (one report), they mainly were using tactical communications between higher and lower echelons (two reports) and briefings (three reports) when the simple match cognitive process was triggered. The troop commanders also used tactical communications and briefings (two reports for each source), but additionally, they identified live sensor feeds (eight reports), reconnaissance or "eyes on" (six reports), and staff discussions between higher and lower echelons (three reports) as principal triggering sources. We believe that the troop commanders' highlighting of these additional sources indicates the high priority placed upon real-time information as key to survival in a close battle area. The importance of these types of sources was also reinforced by the troop commanders in their comments recorded during the focus group discussions (see Section 4).

Table 6

"Sources" of Features, Cues, Indicators, or Patterns in Current Situation, Which Helped Trigger the "Simple Match" Decision Process

Sources to help see features, cues, and so forth	Commander-deputy		Troop commanders		Total	
	No.	Percent	No.	Percent	No.	Percent
Paper maps	0	0	0	0		0
Large screen displays	3	9	2	6	5	15
Tactics, techniques, and procedures (TTPs)	0	0	0	0		0
Briefings	3	9	2	6	5	15
War gaming	0	0	0	0		0
Synchronization matrix	1	2	0	0	1	2
Intelligence preparation of the battlefield (IPB)	1	2	0	0	1	2
Modified combined obstacle overlay (MCOO)	0	0	0	0		0
Reconnaissance "eyes on"	1	2	6	17	7	19
Staff discussions or input (e.g., TOC 3, XO, higher-lower echelon, etc.)	0	0	3	9	3	9
ATCCS information or displays (maneuver control system [MCS], all-source analysis system [ASAS], etc.)	0	0	0	0		0
Live sensor feeds (i.e., joint surveillance target attack radar system [JSTARS], Army missile defense workstation [AMDWS], or other, i.e., ModSAF)	0	0	8	22	8	22
Tactical communications (with higher, lower, adjacent units or echelons)	2	6	2	6	4	12
Rehearsals and battle drills	0	0	1	2	1	2
Decision support template	0	0	0	0		0
Fire support plan	0	0	1	2	1	2
ADA plan	0	0	0	0		0
Other (ModSAF)	0	0	1	2	1	2
Total						100

As shown in Figure 2, the WMDS graphically illustrates this difference between the senior and junior commanders in the "principal" sources of information used to comprehend the current situation and trigger the "Simple Match" decision process.

Euclidean Distance Model- Weighted Multi-Dimensional Scaling

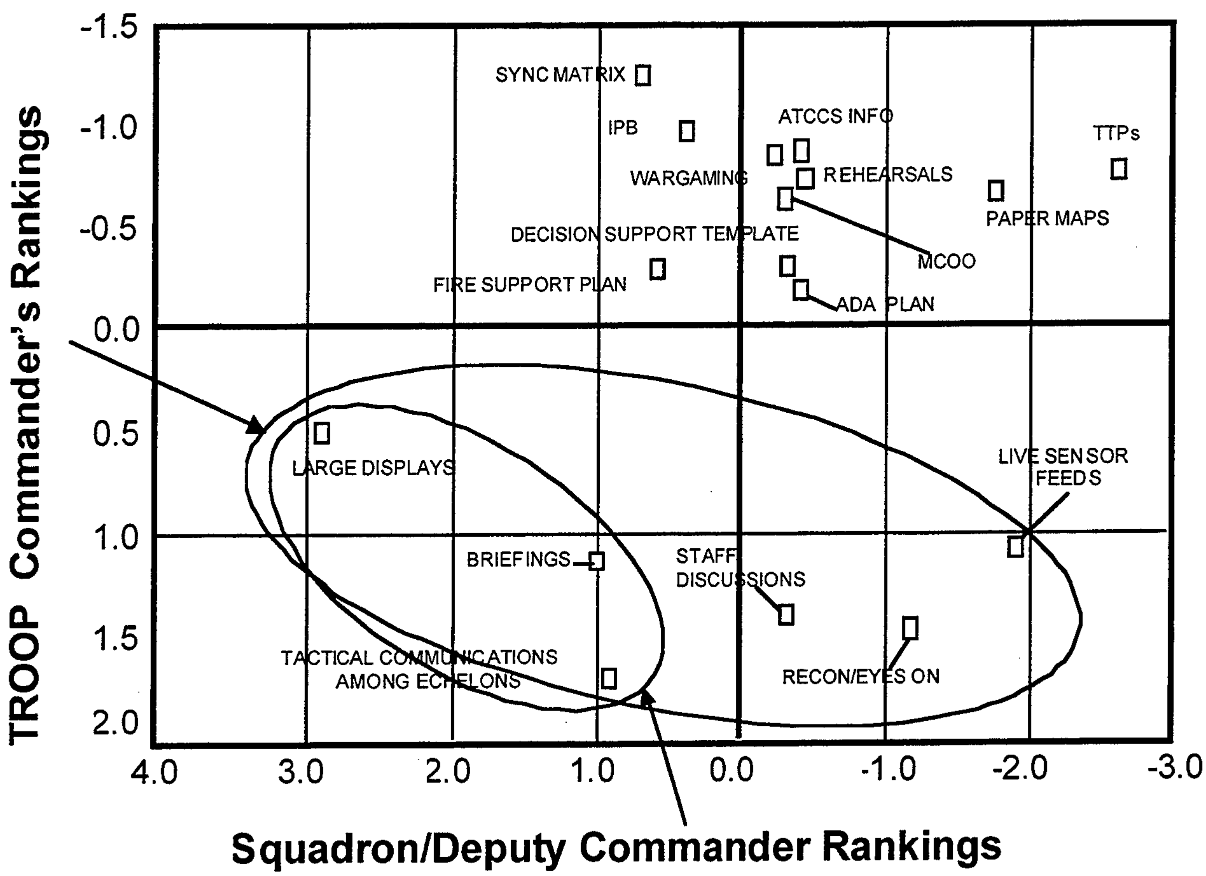


Figure 2. Multi-dimensional scaling of principal "sources" used by senior and junior decision makers.

DTLOMS Implications

A recurring insight from ARL's support of the Army's ongoing series of digitized exercises is the need for an effective CRP graphic tailored to the commander's information needs at his or her echelon of battle. As was seen in such exercises as the division AWE (DAWE), and the Prairie Warrior series, commanders at higher echelons need information about the "big picture" operation and supporting information from staff briefings (e.g., brigade up-date briefs [BUBs] were used at the brigade TOC during the DAWE), and specific detailed data from tactical communications with higher and lower level commanders. On the other hand, commanders at lower echelons have a great need for near real-time information about enemy locations and disposition as well as information about the larger battle picture. This general finding is corroborated in the BCR III data presented here and suggests that while the ModSAF display provided "data" as far down as the entity level, live sensor feeds had to be enhanced with staff discussions and direct communications with reconnaissance having "eyes on" in order to convert the data points into knowledge about probable enemy intent, potential threats, or developing opportunities for exploitation. In support of this human-centered fusion process, potential new ModSAF-based information management capabilities could include emphasis on creating agent-based capabilities to fuse data into knowledge to support situation assessment and decision making.

Types of Uncertainty Experienced and Coping Strategies Used

In this component of the DMSRP, the respondent is asked if any uncertainty was experienced during the decision event. If the answer was "yes," the respondent was asked to identify the type of uncertainty experienced and the strategies used to cope with the uncertainty. Given the level of situation awareness (> 90%) expected in the ModSAF simulation, it was surprising to see the degree of uncertainty reported by the BCR III commanders. While the decision makers experienced no uncertainty in 17 of the decision events, a degree of uncertainty was associated with 21 decision events, as shown in Table 7. Here, it is interesting to note that the commander-deputy commanders, with their combination of ModSAF-fed displays, live sensors feeds, and support staff, experienced uncertainty, as did the troop commanders. As shown, 12 of the 21 decision makers experienced uncertainty because of incomplete information about the situation. Another four claimed to have had an incomplete understanding of the situation even with complete information. Undifferentiated alternatives (3) and confusion because of many meanings or interpretations (2) accounted for the remaining reasons for uncertainty. Similar frequency response patterns were found between the senior and junior commanders. Note that the presence of uncertainty was corroborated in the C^2DEI data (see Table 22) where the various commanders' assessments of "enemy understanding" (i.e., salient aspects of this METT-TC dimension were recognized and known by the decision maker) were rated as less than certain.

As shown in Table 8, to cope with the uncertainty experienced, eight decision makers collected more information to reduce uncertainty, 14 made assumptions to cope with uncertainty, five formed understanding using plausible reasoning, five weighed "pros" and "cons," seven relied on intuition or experience, and one used forestalling.

No trend differences could be found between senior and junior decision makers regarding the types of uncertainty experienced and coping strategies used (x^2 = 8.6, sig. = 0.13).

Table 7

Types of Uncertainty Experienced

Types of uncertainty experienced	Commander-deputy No.	Commander-deputy Percent	Troop commanders No.	Troop commanders Percent	Total No.	Total Percent
Incomplete information about the situation	4	19	8	38	12	57
Incomplete understanding of the situation even with complete information	1	5	3	14	4	19
Conflict between undifferentiated alternatives	1	5	2	9	3	14
Confused by equivocality (i.e., too many meanings, significances or interpretations of the current situation)	1	5	1	5	2	10
Total	7	33	14	67	21	100

Table 8

Strategies for Coping With Uncertainty

Strategies for coping with uncertainty	Commander-deputy No.	Commander-deputy Percent	Troop commanders No.	Troop commanders Percent	Total No.	Total Percent
Uncertainty reduction: collect more information, refined problem framework, relied on SOP and doctrine	1	3	7	17	8	20
Made assumptions that dealt with the uncertainty (i.e., constructed "what if" scenarios to improve understanding)	5	13	9	22	14	35
Plausible reasoning: formed understanding that provided "just enough" certainty to eliminate equivocality or confusion in meaning	2	5	3	8	5	13
Weighed pros and cons of conflicting alternatives (if no single "good enough" option presented)	0	0	5	13	5	13
Suppression (simply ignored the uncertainty) relied on intuition or experience; took calculated risk(s)	2	5	5	13	7	18
Forestalling as a way of dealing with uncertainty	0	0	1	3	1	3
Total	10[a]	26	30[a]	74	40[a]	100

[a]Respondents were permitted to select more than one coping strategy.

DTLOMS Implications

With reference to the BRC III sub-issue question (*What is the impact of situational awareness certainty and its cognitive effect on decision making, information request, and staff dynamics?*) and based on the DMSRP data, the current ModSAF display capabilities do not appear to provide complete situational awareness "certainty." Although currently configured ModSAF displays can provide data as far down as the individual entity level, they provide neither a graphic CRP nor commander-tailorable "fused" CCIR information of immediate utility for situation assessment and decision making (e.g., agent-based probable enemy intent options, potential threat projections or enemy emergent weaknesses ripe for exploitation (see Section 3, ARL Observation-Based Insights, which address these points in more detail). Thus, intelligent agent technology could serve as a "fusion engine" within ModSAF-type software or displays to develop and maintain a commander-tailored graphical CRP and to address context-specific CCIR information in real time.

Patterns of Commander-Staff Interaction

This component describes the patterns of commander-staff interaction associated with the critical decision event. As shown in Table 9, 19 (50%) of the decision makers made their decisions in isolation while 11 (29%) made their decisions within the context of a well-formed team. In the remaining cases, three (8%) decision makers first set the general decision framework and then allowed the staff to complete the details, three (8%) commanders delegated the decision to another staff member while monitoring the overall process, and the remaining two (5%) decision makers hierarchically directed the staff to provide specific input and then integrated this information to make the final decision. A significant difference was found between the senior and junior commanders in the pattern of Commander x Staff interaction ($x^2 = 16.5$, sig. = .002).

Table 9

Pattern of Commander-Staff Interaction

Category of interaction		No.	Percent
Well-formed team		11	29
Commander sets framework		3	8
Commander hierarchically directs		2	5
Commander delegates		3	8
Commander makes decision (without staff input)		19	50
	Total	38	100

DTLOMS Implications

In addition to unit-level visualizations, a "screen insert" or second display is needed to provide a CRP graphic representation of the "bigger picture" to allow lower level commanders and support staff to simultaneously view the CRP to maintain higher level situation awareness without (as one commander described it) "losing the bubble," relative to their narrowly focused current fight operations. In sharing situational awareness, the support staff is in a better position to assist the commander in situational assessment and decision making.

Cognitive Workload Estimate

This component of the DMSRP provided the various elements of the NASA TLX workload assessment metric. The results for each element are provided next.

Mental Demand

Mental demand varied across the decision events. Ten (26%) decision makers rated the mental demand as "very low" or "low" (see Table 10). Fourteen (37%) of the decisions made were rated by the commanders as representing only a moderate mental demand. Finally, 14 (37%) commanders rated the decision events as having high to very high mental demand. No significant difference was found between senior and junior commanders' mental demand ratings ($x^2 = 5.3$, sig. = 0.25).

Table 10

Mental Demand

Rating	No.	Percent
Very low	7	18
Low	3	8
Moderate	14	37
High	12	31
Very high	2	6
Total	38	100

Physical Demand

Because this experiment was conducted in a command post exercise (CPX) type environment, a large majority (32 or 84%) of the respondents indicated that the decisions required very low to low physical demand (see Table 11). No significant difference was found between senior and junior commanders' physical demand ratings ($x^2 = 4.2$, sig. = 0.17).

Table 11

Physical Demand

Rating	No.	Percent
Very low	18	47
Low	14	37
Moderate	3	8
High	2	5
Very high	1	3
Total	38	100

Temporal Demand

In the opinion of the commanders, decisions requiring low, moderate, and high time demand were normally distributed across the 38 critical decision events, with moderate time demand indicated in 14 of the reports (see Table 12). No significant difference was found between senior and junior commanders' time demand ratings ($x^2 = 1.5$, sig. = 0.81).

Table 12

Temporal Demand

Rating	No.	Percent
Very low	6	16
Low	6	16
Moderate	14	37
High	7	18
Very high	5	13
Total	38	100

Performance

As shown in Table 13, the BCR III commanders felt that they were moderately to highly successful in overcoming any problems associated with the critical event decisions. No significant difference was found between the senior and junior commanders' performance ratings ($x^2 = 7.4$, sig. = 0.19).

Table 13

Performance

Rating	No.	Percent
Very low	2	3
Low	4	11
Moderate	9	24
High	12	32
Very high	11	30
Total	38	100

Effort

The effort that the commanders expended during most of the decision events was rated at moderate to low (see Table 14). No significant difference was found between the commanders' effort ratings ($x^2 = 7.1$, sig. = 0.16).

Table 14

Effort

Rating	No.	Percent
Very low	12	31
Low	9	24
Moderate	12	32
High	5	13
Very high	0	0
Total	38	100

Frustration

As shown in Table 15, moderate levels of frustration were experienced by the commander-deputy commander. The frustration level for the troop commanders was rated primarily as very low or low during the critical decision events ($x^2 = 13.4$, sig. = 0.01).

Table 15

Frustration Levels

Rating	Commander-Deputy	Troop commanders	No.	Percent
Very low	2/5	8/21	10	26
Low	2/5	7/19	9	24
Moderate	9/24	5/13	14	37
High	1/2	3/9	4	11
Very high	0/0	1/2	1	2
Total	14/36	24/64	38	100

DTLOMS Implications

With reference to the BRC III sub-issue question (*What is the impact of situational awareness certainty and its cognitive effect on decision making, information request, and staff dynamics?*), implications are associated with the situational awareness uncertainty reported. One likely effect was moderate to very high frustration, which, as noted in Section 3 (Observation-based Insights), might have been prompted by the feelings of lack of control and lack of timely CCIR resolution experienced by the squadron commander and the micro-management pressures and the lack of "big picture" awareness experienced by the troop commanders. Thus, the uncertainty and frustration levels experienced were most likely significant contributors to the high "information request" levels observed and the "micro-management staff dynamics" also observed by ARL and reported by the troop commanders (see Section 4) during BCR III.

Information-Processing Activities

As shown in Table 16, this component of the DMSRP contains descriptors of 20 separate information-processing activities and was one of the most challenging sections of the

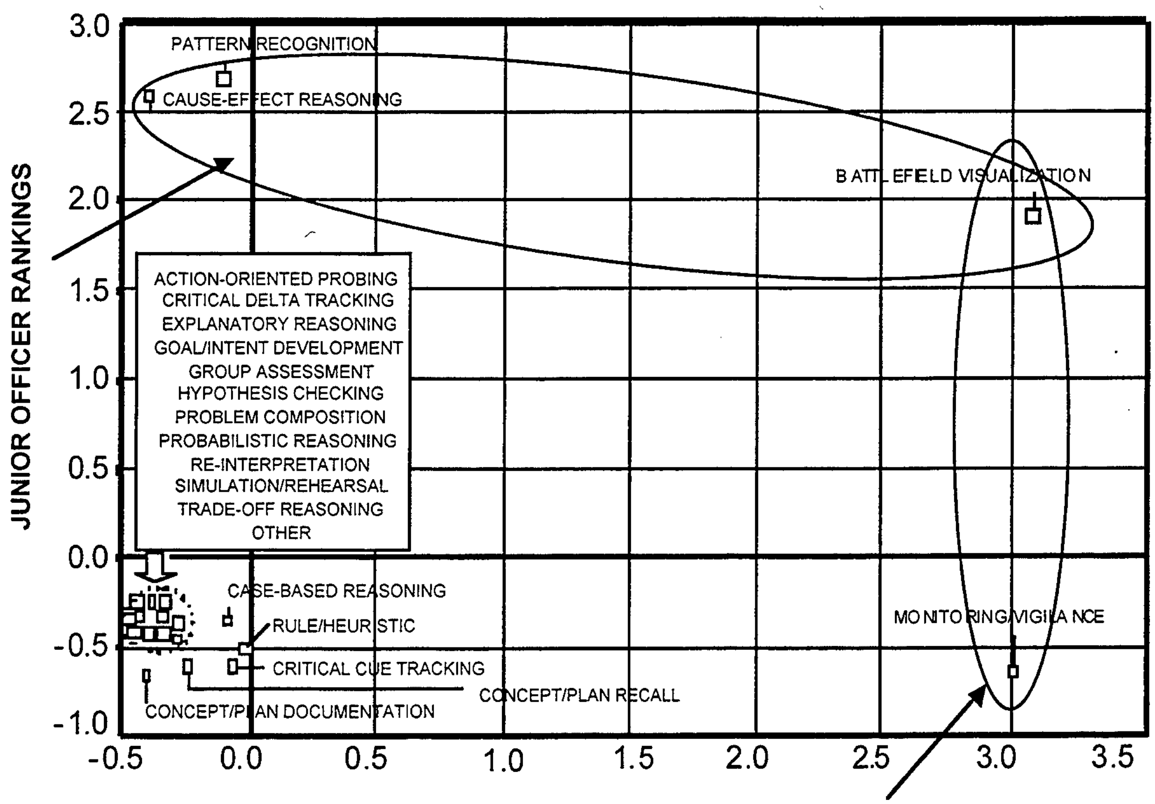
Table 16

Information-Processing Activities

	Cognitive activity	Descriptor
1	Monitoring or vigilance	Monitored dynamic information display(s) to detect significant event or trend against background of battle space noise and clutter
2	Critical cue tracking	Mentally isolated and tracked a critical object or event that served as a qualitative indicator of a broader activity or trend within the battle space
3	Critical delta tracking	Computed or monitored some functional, geographic, or temporal metric that provided a quantitative indication (tactical delta) of current situation versus plan
4	Group assessment	Interacted with other battle command personnel to gain an intuitive sense of confidence, readiness, or feeling for a situation or idea
5	Rule or heuristic	Mentally applied a doctrinal or experiential rule or heuristic to interpret or order data, develop an option, evaluate a choice, or confirm or deny an expectancy
6	Hypothesis checking	Deliberately sought evidential data of a directed or specific nature in order to validate an operational hypothesis or confirm or deny a battle space expectancy
7	Goal or intent development	Developed mission goal(s) or intent to clarify, deconflict, and prioritize operational objectives, desired battlefield end state, and constraints or time lines
8	Battlefield visualization	Developed a mental image of battle space operations in order to highlight key geographic or temporal relationships vis-à-vis goals, intent, and plans
9	Simulation or rehearsal	Dynamically projected battle space activities over time to evaluate critical roles, synchronize events, project outcomes, and identify future decision points
10	Explanatory reasoning	Developed and evaluated an event sequence (e.g., story, script) to logically explain a situation, define an issue, or refine or assess a response option
11	Problem decomposition	Broke down or simplified overall problem in order to mentally focus on only one element or dimension of the battle space problem at a time
12	Pattern recognition	Automatically reacted to a familiar pattern of objects, activities, or events within the battle space as a meaningful whole, based on past experience or knowledge
13	Case-based reasoning	Deliberately compared current battle space situation to past, familiar experiences in order to structure thinking, focus on issues, define responses, or test options
14	Reinterpretation (devil's advocate)	Deliberately adopted an alternate point of view, challenged beliefs, or uncovered a hidden assumption in order to gain additional problem insight
15	Probabilistic reasoning	Mentally viewed battle space operations in terms of uncertainties, probabilities, and event chains in order to highlight potential risks and contingencies
16	Action-oriented probing	Deliberately took specific probing action for the purpose of gaining feedback and reducing uncertainty before committing to a broader response option
17	Cause-effect reasoning	Explored or identified specific cause-and-effect relationships among key elements of the battle space
18	Trade-off reasoning	Deliberately compared the relative pros and cons of identified response options vis-à-vis accepted evaluation criteria
19	Concept or plan documentation	Prepared a visual sketch or narrative description of a concept or plan in order to communicate specific ideas to other battle command personnel
20	Concept or plan recall	Deliberately recalled specific details of a concept or plan previously developed within the battle command process

instrument for commanders to complete. The activities listed include those that can be associated with monitoring processes, visualizations, and situational assessment methods, as well as various forms of reasoning and critical thinking skills. Some of the activity descriptors, while rigorous with respect to implied meaning, nevertheless contain process overlaps with other activities and thus require careful reading to detect subtle nuances associated with application. In the data analysis, the utility of the WMDS, coupled with discriminant analysis, was effective in quantifying the information-processing activities conducted by the senior versus junior decision makers (squadron commander [LTC] and deputy commander [MAJ] versus the troop commanders [Captains]). Here, it was found that a significant difference existed between these two groups in the type of information-processing activities.

As can be seen in Figure 3, the WMDS indicated that the senior decision makers used battlefield visualization and a combination of monitoring and vigilance activities to process information in support of decision making. While the junior commanders also used battlefield visualization, they additionally relied on pattern recognition and cause-and-effect reasoning as primary information-gathering and cognitive processing activities.



S-stress = 0.18, RSq = 0.96, Wilks' λ = 0.61, significance = 0.03.

Figure 3. Information-processing activities' rankings as a function of senior versus junior officer decision makers, analyzed by a multi-dimensional scaling method.

DTLOMS Implications

The literature about decision making strongly suggests that the cognitive underpinnings of expertise are qualitatively different from the general rule-based processes employed by novices (Klein, 1993, 1997; Rouse & Valusek, 1993). The information-processing activities noted by the BCR III commanders are consistent with research findings that suggest that experts employ higher levels of abstract knowledge, use pattern recognition to activate relevant knowledge structures, select a single COA, and then assess the selected COA by mental simulation of its implementation. Results presented here suggest that future ModSAF capabilities that assist decision makers in (a) focusing on the relevant cues in a situation during monitoring, (b) fusing data points into information for more effective pattern recognition, (c) visualizing emerging threats or opportunities for exploitation of weaknesses, and (d) providing agent-based capabilities to perform cause-effect assessment of selected COAs, can serve as cognitive aids to the human-centered processes employed by the military decision maker.

DMSRP Instrument—Conclusions and Future Directions

The DMSRP application identified a number of patterns regarding usage of information from various sources and the perceived significance of selective information as a function of command echelon. Multi-dimensional scaling solutions were obtained which graphically portrayed how commanders linked information in the process of situation assessment and decision making. The commander-deputy commander focused on operational indicators that were keyed to aspects of battlefield shaping and decisive engagements. By contrast, the troop commanders placed more emphasis on information of direct consequence to the unit or entity-level fight. Taken as a whole, the results from the application of the DMSRP during BCR III have demonstrated the instrument's utility for providing structured diagnostic insights into the processes related to cognition as it appears to function in complex technology-supported military decision making. Ensuing applications of the instrument within the BCR venue would continue to map the cognitive constituents of military decision making as supported by advanced ModSAF-like technology capabilities. DMSRP-tracked changes in these cognitive processes (as a function of the technological and organizational capabilities modeled within the continuing BCR experimental framework) will serve as an MMBL guide towards the objective future war fighter suite of human-centered decision aids and battlefield visualization tools.

SECTION 2: C^{2}DEI-BASED RESULTS

Overview of the C^{2}DEI

The dynamics and complexities associated with modern military engagements, from peace keeping to major regional conflict, demand that the information associated with such environments be carefully selected, framed, and presented to facilitate effective decision making at all levels of command. Our previous research (Cook, 1998; Cook, Leedom, Grynovicki, & Golden, 1999) suggests that commanders recognize and value the six fundamental dimensions represented by the military acronym METT-TC (mission, enemy, troops, terrain and weather, time available, and civilian considerations) and that the commanders are able to assess the relative significance of the dimensions and their level of current understanding for discrete decisions. The BCR III experiment provided an ideal arena in which to continue and replicate our investigations of METT-TC dimensions and their associations with representative battle command decisions and processes as represented in the C^{2}DEI. In addition to replicating procedures from previous research (Cook et al., 1999), the ARL team was also interested in perceptions of certain aspects of the information technology (IT) available to the decision makers (e.g., ModSAF, communications, etc.) such as functionality, availability, and reliability.

The C^{2}DEI was developed as a self-report instrument specifically to assess the significance of METT-TC dimensions during the MDMP. Decision-maker assessments of selected aspects of the physical environment were also made. METT-TC dimensions were measured using 5-point "Likert" scales ranging from "very low" to "very high" for both "significance" and "level of understanding" of each dimension. Significance was operationally defined as the degree to which the dimension was important for the particular decision. Understanding was operationally defined as the degree to which the salient aspects of the dimension were recognized and known to the decision maker. Aspects of IT (functionality, availability, and reliability) and impact of the physical environment (humidity, lighting, temperature, vibration, crowding, and noise), were measured using 5-point "Likert" scales ranging from "very low" to "very high." (Note that the C^{2}DEI-based information related to decision types and decision-maker background [referenced next] was extracted from the DMSRP-based data.)

Hypothesis

It was hypothesized that effective combat decision making would be influenced, in part, by the perceived significance and level of understanding of selected dimensions of battle-tested frameworks associated with combat environments. Furthermore, it was felt that the dimensions traditionally represented by the military acronym METT-TC would represent salient dimensions of environmental complexity and would represent important "chunks" of information during the MDMP. It was also believed that the decision maker's reported understanding of these dimensions and their relative significance to the decision would vary according to the types of decisions (e.g., significant change versus minor adjustments). Because there were no "civilian" aspects within the scenarios being employed, it was hypothesized that decision makers would rate these dimensions as "very low" or "not applicable." Confirmation of this last hypothesis would support the argument that commanders were rating dimensions independently and were not subject to a response set or bias. Regarding IT, it was hypothesized that current IT (e.g., ModSAF, Army battle command system [ABCS]) would support the decision process and be perceived as favorable in terms of functionality, availability, and reliability.

Data Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS®) for Windows™ Version 6.5. Cases with missing values were deleted listwise during multivariate analyses.

Results

The primary thrust of this segment of the BCR III investigation was to assess the relative "significance" and "level of understanding" of each dimension of METT-TC during a series of command decisions and to isolate relationships among METT-TC dimensions and types of decisions and aspects of IT environment. An ancillary objective was to assess the impact of the physical environment on decision making. During the 2-week data collection period, 38 command decisions were identified, and METT-TC, IT, physical environment data were collected using the C^2DEI. Background and decision type variables were extracted from the DMSRP. Of the 38 command decisions, 16 were considered to be "significant" (i.e., a significant change in the implemented COA), and 22 were considered to be "minor" adjustments to the currently implemented COA.

As shown in Table 17, for each of the dimensions represented by METT-TC, decision makers reported high levels of both "significance" and "understanding," except for "civilian considerations," which were not present in the experimental scenarios.

Table 17

Descriptive Statistics for METT-TC Dimensions

Variable	Mean	SD[a]	N
Mission significance	4.03	.74	37
Mission understanding	4.38	.68	36
Enemy significance	4.32	1.00	37
Enemy understanding	3.89	.91	37
Troops significance	4.06	1.15	36
Troops understanding	4.42	.69	36
Terrain significance	4.06	1.15	36
Terrain understanding	3.92	1.25	36
Time significance	4.06	1.15	38
Time understanding	3.68	.96	38
Civilian significance	NA[b]	NA	NA
Civilian understanding	NA	NA	NA

[a]SD = standard deviation
[b]NA = not applicable

Correlations among METT-TC dimensions are presented in Table 18 and show a moderate to high degree of independence. Mean values of understanding and significance for each dimension remained consistent across the 2-week period.

For each of the IT dimensions, decision makers reported high levels of availability, functionality, and reliability (see Table 19). Correlations among IT dimensions are presented in Table 20 and show a high degree of dependence (i.e., all measuring a high degree of satisfaction). Mean values for IT dimensions remained consistent across the 2-week period.

As shown in Table 21, decision makers reported low-level effects of the physical environment on their decision making. Mean values for IT dimensions remained steady across the 2-week period.

In Table 22, significant differences were noted between the decision maker's assessment of enemy understanding according to decision type; lower levels of understanding were reported in the DMSRP for major change in COA decisions than for minor adjustments in COA decisions. (Note that the presence of uncertainty was corroborated in the DMSRP data [see Table 7] wherein the commanders indicated experiencing uncertainty in 21 of the 38 critical decision events reported.)

Table 18

Correlations Among METT-TC Dimensions

METT-TC dimensions	1	2	3	4	5	6	7	8	9	10	11	12
1. Mission significance	--	.51*	.10	-.09	.17	.36*	.04	.27	.27	.01	NA	NA
2. Mission understanding	--	--	.07	.23	.08	.61*	.36*	.75*	.01	.34*	NA	NA
3. Enemy significance	--	--	--	-.05	.66*	.11	-.25	-.01	.10	-.32*	NA	NA
4. Enemy understanding	--	--	--	--	-.17	.02	.50*	.27	.07	.56*	NA	NA
5. Troops significance	--	--	--	--	--	.37*	-.44*	-.18	.21	-.30	NA	NA
6. Troops understanding	--	--	--	--	--	--	.06	.26	.21	.25	NA	NA
7. Terrain significance	--	--	--	--	--	--	--	.41*	.06	.52*	NA	NA
8. Terrain understanding	--	--	--	--	--	--	--	--	.02	.47*	NA	NA
9. Time significance	--	--	--	--	--	--	--	--	--	.10	NA	NA
10. Time understanding	--	--	--	--	--	--	--	--	--	--	NA	NA
11. Civilian significance	--	--	--	--	--	--	--	--	--	--	--	--
12. Civilian understanding	--	--	--	--	--	--	--	--	--	--	--	--

Notes. 1. Only complete cases were included in the analysis;
2. NA = not applicable for this scenario;
* = $p < .05$

Table 19

Descriptive Statistics for Information Technology Dimensions

Variable	Mean	SD	N
Availability	4.21	.96	38
Functionality	4.26	.83	38
Reliability	4.35	.96	38

Table 20

Correlations Among Information Technology Dimensions

Information technology dimensions	1	2	3
1. Availability	--	.67*	.68*
2. Reliability	--	--	.90*
3. Functionality	--	--	--

Note. 1. Only complete cases were included in the analysis;
* = $p < .05$

Table 21

Descriptive Statistics for Physical Environment

Variable	Mean	SD	N
Humidity	1.14	.35	38
Lighting	1.14	.35	38
Temperature	1.14	.35	38
Vibration	1.14	.25	38
Crowding	1.38	.76	38
Noise	1.68	.97	38

Table 22

Enemy Understanding According to Decision Type

Decision type	Mean	SD	Cases
Major changes in COA	3.44	.96	16
Minor adjustments in COA	4.25	.70	21

$F(1,35) = 8.58$, $p < .01$

Significant differences were noted (see Table 23) between the decision maker's assessment of enemy significance according to decision type; higher levels of significance were reported in the DMSRP for major change decisions than for minor adjustment decisions.

Table 23

Enemy Significance According to Decision Type

Decision type	Mean	SD	Cases
Major changes in COA	4.75	.45	16
Minor adjustments in COA	4.00	1.1	21

$F(1,35) = 5.77$, $p < .05$

Significant differences were noted (see Table 24) between the decision maker's assessment of time understanding according to decision type; higher levels of significance were reported for minor adjustment decisions than for major change decisions.

Significant differences were noted (see Table 25) between the decision maker's assessment of troops (own) significance according to decision type; higher levels of significance were reported for major change decisions than for minor adjustment decisions.

Table 24

Time Understanding According to Decision Type

Decision type	Mean	SD	Cases
Major change in COA	3.25	.86	16
Minor adjustments in COA	4.00	.93	22

$F(1,36) = 6.47, p < .05$

Table 25

Troops Significance According to Decision Type

Decision type	Mean	SD	Cases
Major change in COA	4.67	.61	15
Minor adjustments in COA	3.62	1.24	21

$F(1,34) = 9.00, p < .01$

As shown in Table 26, significant differences were noted between the decision maker's assessment of IT functionality according to decision type; higher levels of functionality were reported for major change decisions than for minor adjustment decisions.

Table 26

IT Functionality According to Decision Type

Decision type	Mean	SD	Cases
Major change in COA	4.69	.48	16
Minor adjustments in COA	3.95	.90	22

$F(1,36) = 8.79, p < .01$

Significant differences were noted (see Table 27) between the decision maker's assessment of IT availability according to decision type; higher levels of availability were reported for major change decisions than for minor adjustment decisions.

Table 27

IT Availability According to Decision Type

Decision type	Mean	SD	Cases
Major change in COA	4.69	.48	16
Minor adjustments to COA	4.10	.77	21

$F\ (1,35) = 7.31, p < .05$

C²DEI Instrument—Conclusions and Future Directions

Results of this investigation replicate earlier findings regarding the importance of METT-TC dimensions during the military decision-making process. They support the argument that the six dimensions of METT-TC represent fundamental sources of battle space "complexity" and can be useful for organizing relationships that are changing and emerging and for knowledge necessary for decision making in near real time. Specifically, the BCR III data provide support and validation for the basic hypothesis that the six dimensions of METT-TC represent fundamentally significant dimensions of the command decision space and that both the significance and understanding of these variables to the decision maker can vary according to the type of decision required. The BCR III data also confirm that the decision makers were satisfied with the IT available to them in support of their decisions and that the physical environment of an experiment such as BCR III had little effect on decision-making ability.

Knowledge gained from this investigation will be applied in support of U.S. Army objectives to

1. Tailor and guide future hypothesis testing at major Army and joint service experiments; and

2. Structure the representation of METT-TC dimensions, main effects, interactions and dependencies, and present them in a clear and "simple" manner to support the cognitive requirements and capabilities of decision makers.

In summary, the use of METT-TC as indicators of environmental complexity in combat situations appears to have both high degrees of face and external validity, and this investigation has provided replication of previous findings supporting the validity and reliability of the measures. Once the findings have been replicated in several additional representative military exercises, cognitive engineering and hardware-software implications for command center design will be presented. Further research is indicated to assess internal validity and reliability of the measures and to assess the implications for "cognitive engineering of the digital battlefield."

SECTION 3: OBSERVATION-BASED INSIGHTS OF THE BCR III OPERATIONS

Shortcomings were noted during the BCR III trials, which were directly related to the limited ModSAF-based training and skill levels of some of the ACR squadron staff elements. Since these shortcomings would be expected to disappear with increased on-the-job (OJT) training and experience, the insights presented here focus primarily on over-arching issues associated with the ModSAF-based digitization concepts as they supported critical command decision-making processes.

BCR III MDMP Process Abbreviation

As shown in Figure 4, relative to FM 100-5, the squadron commander employed an abbreviated version of the MDMP.

This abbreviated process was similar to that observed during BCR II, and we believe that advanced ModSAF-like visualization and decision aids' technologies will foster such process changes. In BCR III, the normal planning products (including intelligence estimates, concept of operations, and OPORDS or fragmentary orders [FRAGOs]) were briefed verbally to selected squadron staff with the aid of an electronic white board. No formal paper products were generated or distributed. Even the warning orders and FRAGOs from the regimental commander were given by electronic mail and white board, with only the squadron commander and executive officer (XO) in video teleconference (VTC) attendance. Following receipt and clarification of intent, the squadron commander mentally selected a single COA and subsequently discussed his concept of operation with selected troop commanders and other key staff over the command net. In spite of this brief verbal exchange with his troop commanders, the squadron commander never levied the requirement for a briefing about specific troop-level plans for execution. The rationale for this lack of a planning and briefing process was unclear. One possible explanation might be that, given the level of situational awareness (SA), the squadron commander may have believed

	A	B	
	Military Decision-making Process (FM 101-5) (MDMP)	Squadron Commander's Application of the Principles of real-time Battlefield Visualization-Based SA	
	Issued by HHQ . . . HHQ mission and Task Organization HHQ Comdr.'s Intent (Purpose, Method, End State) HHQ Specified Tasks to Subordinate Commands	OPORD issued by Squadron Commander Change of Mission Current Operations 1-12 Hours Out	Future Operations 72 Hours Out
1	★ Receipt of Mission Commander's Orientation Initial guidance to Staff	Receive Change of Mission via automated FRAGO Squadron Commander Studies Change	Sqdn Commander/XO Receive Warning Order via Whiteboard from TF Commander Sqdn. Commander Clarifies Intent
2	★ Mission Analysis Intelligence Preparation of the Battlefield Specified, Implied, and Essential Tasks Unit Mission Statement	Squadron Commander Mentally Decides on Single COA , then Describes Concept of Operations to CO/Troop Commanders via Electronic Whiteboard	Sqdn. Commander Orients Staff, Clarifies Task and Purpose & Directs Execution of Mission Analysis to Future Ops Staff Based Upon Specified Concept of Operation & COA. identifies Specified, Implied, and Essential Tasks.
3	★ Courses of Action (COA) Development	na	na
4	★ COA Analysis (includes Wargaming, Coordination, Synchronization	Commander Orients Staff on COA via Whiteboard Receives Inputs from Battle Staff, No backbrief on Planned Method of Execution Levied	Future Ops Staff Conduct Detailed Planning & Develop Simplified Graphics. Whiteboard Backbrief to Commander & Selected Staff. Cmdr. Directs Changes & Distribution
5	★ COA Comparison	na	na
6	★ COA Approval/Decision	na	na
7	★ Orders Production	Commander Directs Current Ops Staff to Generate Simplified Graphic Overlay Depicting Terrain Oriented Phase Lines, GCT Sectors, NAIs, EAs, and Distribute	Planning Cells Develop Orders & Overlays for Automatic Distribution (Mission Orders, Simple Graphics)
8	Transition/Preparation by Subordinate and Supporting Units	Transition/Preparation by Subordinate and Supporting Units	Transition/Preparation by Subordinate and Supporting Units
9	Execution	Execution	Execution

★ Actual MDMD Steps Described in FM 101-5

Figure 4. The military decision-making process (MDMP) versus the BCR III battlefield visualization- based decision-making process.

that regardless of the troop's initial plan of operation, the need for and initiation of quick changes would be readily known and immediately executable once operations commenced. This real-time SA-based command-directed "just-in-time" change process was observed continuously throughout the 9 days of the experiment.

In addition to the abbreviated MDMP methodology used, the squadron commander's concept of operation for COA execution, while employing traditional unit boundaries, phase lines, named areas of interest (NAIs), and engagement areas (EAs), was devoid of the fixed sequence of fire and maneuver tactics such as those employed during the BCR II experiment as outlined in Figure 5.

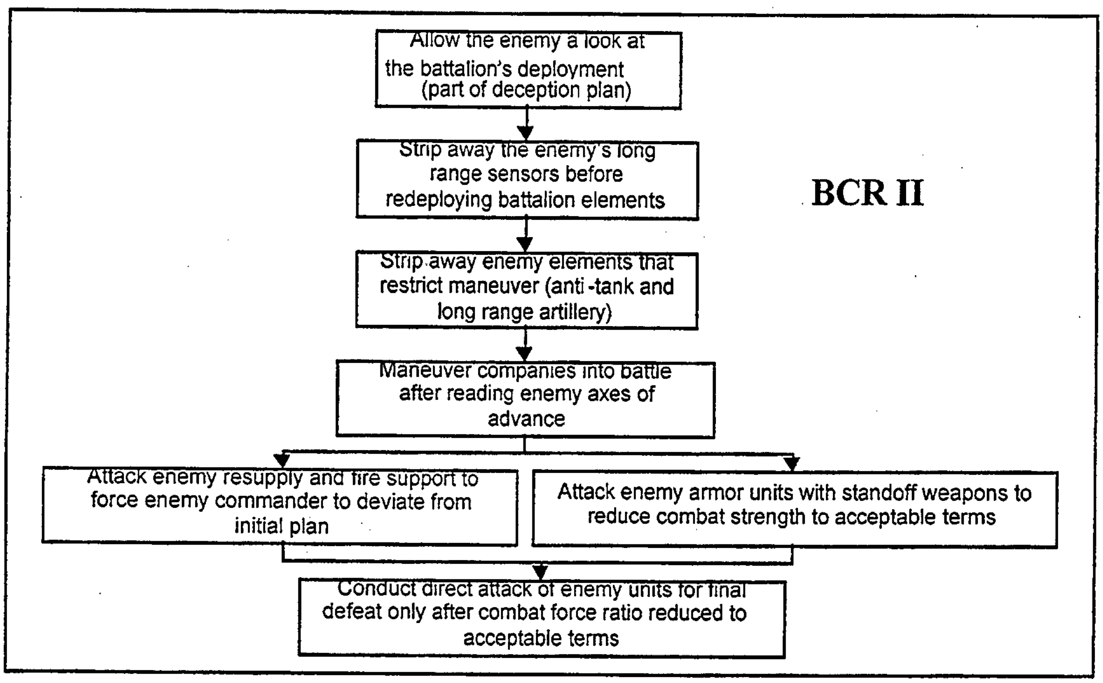


Figure 5. General concept of operation used during the BCR-II experiment.

As shown in Figure 6, the BCR III squadron commander's concept of operation focused on avoiding any direct fire confrontations to minimize the risks to his light forces. Instead, his tactics sought to exploit the real-time SA and advanced sensor and stand-off weapon system capabilities to systematically reduce the enemy force without the need for deception, maneuver, or direct fire engagements (attrition warfare).

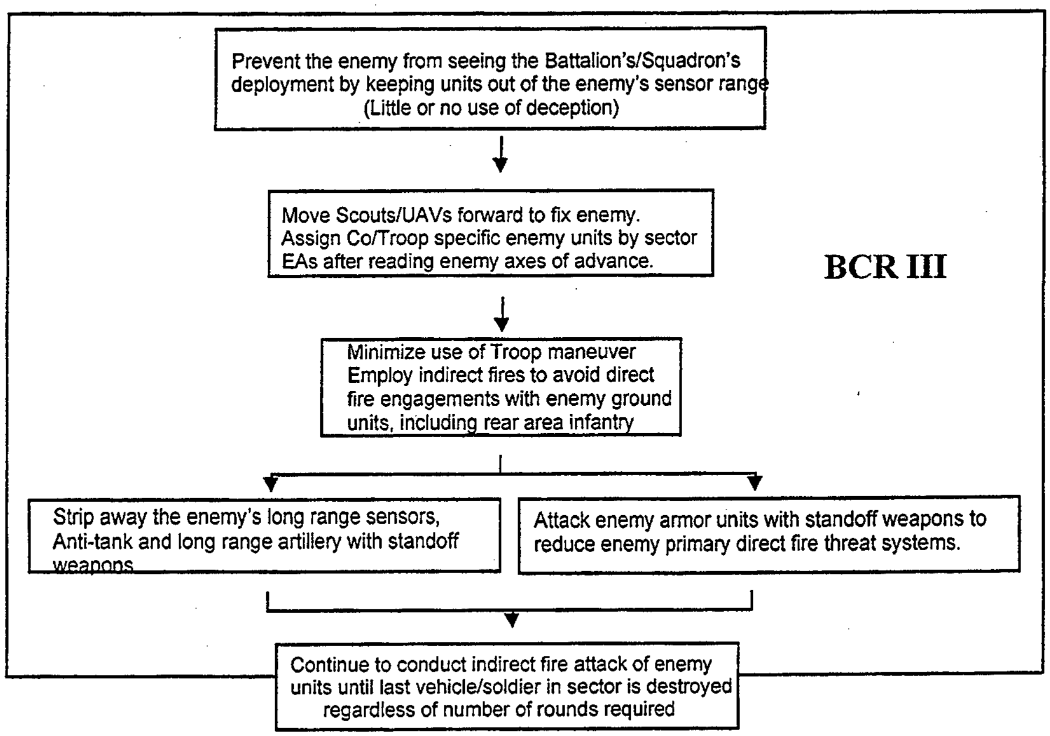


Figure 6. General concept of operation used during the BCR III experiment.

For the most part, target engagement area (EA) locations appeared arbitrary and were employed more as graphic markers for directing operations via white board or radio rather than terrain-based kill zones. This was evident as target engagement decisions were made as part of a rolling sequence of entity-level detection and selective (high threat) system identifications, regardless of where the target was with reference to the designated EAs.

The resulting command and control processes observed in the BCR III experiment could in some cases be characterized as more reactive than proactive. This characterization is attributable mainly to the lack of detailed plans oriented to phase lines, engagement area kill zones, and maneuvers. Instead, much of the battle was "priority of fire-free play" as the commander monitored the enemy's operations and then reacted by directing the troop commanders to engage specific units (or even selected entities) in depth with a sequence of indirect fire operations with target type relative to potential long-range threat to Blue Force assets as the dominant criterion for order of engagement. Thus, direct fire engagements were consistently avoided and rarely occurred throughout the 9 days of experimental trials (most direct fire losses were attributable to enemy aircraft sorties or infantry infiltration into rear areas).

Reconciliation and resolution were essential to ensure that troop operations were properly synchronized, particularly in the areas of indirect fire support (focus and timing), troop sector boundary adjustments, and sensor platform or BDA coverage and collection. To execute this within the squadron task force, good coordination was maintained between the squadron commander and each troop commander by means of the electronic white board conference held before execution but primarily by direct commander-to-commander discussions on the command radio net once the battle commenced. Additionally, the commander proactively encouraged inter-troop command coordination and reinforced this behavior whenever he observed it.

The inherent agility and functional focus of the resulting ModSAF-based C2 processes, with their adoption of a force-oriented (and even entity-oriented) engagement strategy, appeared to have effectively reduced the level and complexity of the distributed information-processing activities across the squadron staff. The squadron task force commander was able to initially articulate and then dynamically refine his concept of operation for reducing the enemy in each engagement in a near real-time context through a direct visual and voice-based procedure consisting of decision, verbal direction, monitoring and assessing, decision, and verbal re-direction (i.e., a commander-directed "just-in-time" change process). Unfortunately, this process appeared at times to be an excessive micro-management staff dynamic.

DTLOMS Implications

Advanced ModSAF-like visualization and decision aids' technologies may foster such procedural changes as abbreviated MDMP processes, including commander-directed "just-in-time" change processes. The level of MDMP process abbreviation (see Figure 4) seen in BCR III, however, may have outpaced the Army's understanding of what the ModSAF-based organizational and process changes portend. If advanced C^2 technologies, as played in the BCR experimental series, are eliminating the need for traditional C^2 measures, then new tools, TTPs, and strategies must be developed for assisting in the management of the novel command group processes (and their potential shortcomings) that are emerging. It is important to note that the ModSAF "entity"-level SA-based process trends may handicap the user organization's planning and sense-making process as a whole, and possibly in real life could expose the organization to the unexpected or surprise events common in the complexity of war. Of concern is the emerging pattern of "attrition warfare" seen in the BCR series in which ModSAF capabilities (real-time situational awareness and advanced sensor and stand-off weapon systems) tend to entice commanders into systematically reducing the enemy force without the need for deception, battle space shaping, or other "smart" tactics. This is in contrast to the doctrine of seeking and exploiting the enemy's weaknesses and thus striving to avoid direct confrontations. To facilitate alternate tactics and doctrinal approaches especially aimed at finding and exploiting enemy weaknesses and windows of opportunity, future ModSAF-type systems should integrate agent-based capabilities to track and structure the representation of the complete set of METT-TC dimensions, main effects, interactions, and dependencies to more effectively represent the complex battle space environment (see CCIR-related insights, which follow).

Within the command and organizational context outlined previously, some of the more important process and technology-based shortcomings observed during BCR III are now discussed.

BCR III Command Process Shortcomings

While moment-to-moment entity-level SA was high in BCR III, an emerging "big picture" schema or squadron area of operations (AO)-based CRP was wanting. Additionally, patterns of command-centered recurring CCIRs went unnoticed by the support staff (the enemy operations and effects officer). The need for creating and maintaining "common and accurate" CRP graphics to synchronize mental models among key staff as the situation dynamically evolves, as well as the need to dynamically manage the capture, fusion, monitoring, and displaying of recurring or evolving CCIR, without resorting to micro-management, are key observation-based issues from the BCR III exercises.

Common Relevant Picture (CRP)

Given the capability of unit, sub-unit, and entity-level vision, commanders spent a relatively large percentage of the time on their ModSAF displays imaged at these detailed levels. This was especially the case at the troop level as these cells executed the detailed battle operations via their single ModSAF display. This effectively limited both the ability of the troop cell to maintain a squadron-level CRP and the level of participation by the supporting NCOs. This limitation was recognized by the troop commanders early in the exercise as they recommended that a second ModSAF display be provided for future experiments so that the NCO could maintain the larger picture SA while the commander fought the battle at the unit or entity level. As highlighted in the DMSRP section (see Table 7), the one unexpected finding, given the level of SA purported with the ModSAF display, was the relatively large number of decision events wherein the troop commanders reported experiencing uncertainty. This finding could be a reflection of the issue associated with the single display at the troop level where the commander (conducting unit or entity-level operations) experienced uncertainty because of the lack of a ready means of maintaining the big picture of events unfolding across the entire squadron AOI without "losing the bubble" at the detailed battle level.

DTLOMS Implications

A need was identified for creating and maintaining a "common and accurate" CRP graphic to synchronize big picture mental models among key staff at various echelons as the situation dynamically evolves. Such requirements have been repeatedly demonstrated over a series of Army exercises (i.e., Warrior Focus, DAWE, and the Prairie Warrior series). While ModSAF provides a God's eye view down to each individual vehicle icon ("eaches"), there is little information that would serve to synchronize various commanders' mental models of the "tactical meaning" in the emerging patterns presented as the battle progresses. This need is corroborated in both the DMSRP data (see Table 7), which indicated that relatively high levels of uncertainty were experienced, and in the C^2DEI data (see Table 22), which reported that the BCR III commanders' assessments of "enemy understanding" (the salient aspects of this METT-TC dimension recognized and known by the decision maker) were at times less than certain. The capabilities of the current ModSAF-based display should be expanded to provide a cyclically updated graphic unit-level icon-based cartoon or snapshot type CRP with the necessary information to communicate the evolving big picture story, including the commander's intent, along with projected enemy intent, likely avenues of approach, and so forth. With the dramatic reduction of planning processes and products, new management processes must evolve to ensure continued common understanding (mental models of intent, task and purpose, concept of operations, etc.) across battle staff operations once execution commences. Also, the management process should foster and maintain the "bigger picture" SA-based initiative of lower echelon commanders and staff.

CCIRs

In spite of the entity-level information available in the experiment, CCIR processing remained a key staff requirement in BCR III. Given the low level of experience of the enemy operations and effects officers, however, CCIR processing was executed in a less than optimal manner, with little or no thought about the passing of events or a given CCIR's continued relevance or immediate utility to the commander's dynamic process of battle monitoring, assessment, and battle space shaping. With some frustration, the squadron commander was observed to repeatedly search the ModSAF display for or request from his staff specific types of information to clarify uncertainties, gain status, and update his situational awareness. Essentially, these actions were necessitated by (a) the commander's limited capacity for monitoring all relevant details of the high tempo combat situation, (b) the critical requirement to obtain CCIR-based readings of emerging battle aspects to support immediate situation assessment and decision-making process needs, and (c) the lack of staff or digitally based information fusion capabilities to feed recurrent and emergent

CCIR needs in a timely fashion. While such information-seeking behavior is considered routine for commanders, the level of detail, the repeatability of the information sought, and the degree of "hands-on" interaction that the commander had with the ModSAF automation in searching for information was not considered routine.

The observed commander's repetitive information-seeking actions included

• From the ModSAF Display: the commander highlighting multiple enemy vehicle icons (from 1 to 10 at a time) sequentially to identify spot report-based vehicle types.

• From the Enemy Operations Officer: the commander, with some frustration, repeatedly requested specific enemy unit locations or projected intentions.

• From the Effects Officer: the commander, with some frustration, repeatedly requested BDA; information about a given remotely piloted vehicle (RPV) asset's location, current planned UAV flight track and time remaining on station; availability and placement of ground scouts and sensors; indirect fire support mission status, time on targets (TOTs) and targeting priorities or the location and range capability of Blue-Red artillery assets, and if commander-specified high priority targets had been engaged or when engagement would commence.

DTLOMS Implications

Such repetitive information-seeking behavior on the part of the commander suggests shortcomings associated with both support staff performance and advanced display capabilities, which drove the information requests at times to micro-management levels with attendant high levels of frustration experienced by all. While additional training will increase staff experience, the commander's information-seeking behaviors provide insights into potential high payoff improvements in advanced ModSAF-like decision aids. For example, to maximize CCIR utility, CCIR-relevant data streams from various sources should be deconflicted and fused by automation-aided staff for dynamic overmatch to the evolving needs of the commander's current (emergent) battle assessment and decision-making tasks. Future ModSAF-type commander displays should have the capability to present the common picture of the battlefield METT-TC information in a more functional and fused form, rather than merely in single entity physical terms. For example, (a) data fusion: upon demand by the ModSAF user, selected Red Force system (i.e., T-90s) spot report data could be instantly summarized, or BDA-based data could be shape coded or highlighted to eliminate the need to look at each icon's spot report individually; (b) historical and planned event visualization: a selected sensor platform's current or planned route could be displayed for continued concurrence or approval and once implemented, the mission flight history and remaining planned route could be displayed upon demand with flight time remaining indicated on the route; or (c) effects data: selected weapon systems icons could be immediately associated with engagement range fans, selected terrain routes could be instantly coded according to specific movement rates, selected unit combat power and opposing force ratios graphics could be displayed in real time for specific direct or indirect fire engagements assessments. Such commander-selected "fused" CCIR information, dynamically presented within the context of the ongoing battle graphics, would reduce the commander's and staff's workload and frustration (as well as associated command net traffic) during critical high tempo battle phases. Such capabilities would facilitate and accelerate the tempo and effectiveness of command battle assessment and decision making, while allowing the staff to be more proactive with anticipating situations and their emerging CCIR requirements.

Additionally, using the insights gained from the application of the ARL C^2DEI instrument, currently configured ModSAF capabilities focus only on the METT dimensions of the METT-TC equation, facilitating communication of mission and commanders' intent, and visualizing enemy and friendly troops locations and dispositions on the terrain. To support alternate tactics and doctrinal approaches especially aimed at finding and exploiting enemy weaknesses and windows of opportunity, future ModSAF-type systems should integrate agent-based capabilities to track and structure the representation of the complete set of METT-TC dimensions, main effects, interactions, and dependencies to more effectively represent the complex battle space environment. These would include agents to assess weather effects on enemy and friendly sensors, weapons and vehicle operations, time dimensions associated with movement rates on alternate axes of advance, day versus night operations, enemy versus friendly troop battle fatigue and psychological factors associated with continuous operations as well as the known complexities associated with psychological operations (PSYOPS) effects within emerging civilian and political dynamics (such as the implications of civilian casualties as a function of weapon type[s] employed).

Micro-Management Change Process

The tendency for advanced display-aided higher level commanders to become frustrated with what appears to be inaction on the part of lower level commanders and to subsequently attempt to micro-manage the battle is a practice that has been predicted with the coming of increased SA capabilities. In fact, the issue of battlefield visualization prompting or facilitating micro-management of the battle at lower echelons by higher echelon commanders has been a phenomenon observed since the U.S. Army began to experiment with digitization (i.e., DAWE, Prairie Warriors, BCR II, etc.). BCR III, however, clearly and unequivocally illustrated the grounds for such dire predictions. Here, SA facilitated and encouraged the micro-management of troop-level battle operations to a degree not previously observed by ARL. In many instances, the squadron commander and key staff fought the battle from the ModSAF screens set to visualize the battle at the individual entity level. With this level of visualization, "time from order to engage a given element to time targets began to appear as killed" or "time from order to move to time entity icons started to move" appeared agonizingly slow (similar to watching water boil). As the entity-level visualization prompted the reaction to expect almost immediate gratification, the virtual action seemed to occur in slow motion rather than the expected nearly instantaneous action. This perceived "lack of response" subsequently prompted the flow of almost constant queries and directions to the troop commanders over the command net. The temptation to direct was so great that in some instances, both the deputy commander and the S2 joined the fray. The result was the commander (and staff) giving a rolling series of detailed directions to lower echelons (e.g., instructing the troop commanders about which specific entity target to engage, when and with what; when and where to move, or asking if a given entity was receiving attention, if a given order had been executed yet, why a given entity had not yet moved or why some directive had not been implemented).

DTLOMS Implications

Such micro-management-centered staff dynamics could greatly increase the cognitive workload, frustration, and stress levels of the lower level commanders in the heat of battle. With this observation, ARL suggested to the BCR III administrative staff that the ModSAF battlefield visualization or situational awareness (BV/SA) be limited to one level down (i.e., battalion-level displays visualize only to company-level icons) and that future BCR experiments play more realistic interactions between the battalion or squadron and higher echelons, as such interactions might tend to focus the battalion commander's attention away from the entity-level display details and more on "big picture" issues. It is interesting to note that during the focus group discussions held at the end of the final AAR, this issue of micro-management was raised by the troop commanders as the "one" aspect of the BCR III exercise that they would change (see Section 4). As an additional related insight, the squadron commander's almost continuous radio net discussions with the troop commanders suggests that regardless of the level of SA (i.e., even to entity-level detail), both face-to-face and net-based verbal dialog will be sought to facilitate reconciliation of perspectives and affect mental model correspondence both horizontally and vertically across the battle command for effective situation assessment and decision making.

Virtual Versus Real-life Span of Control

One trend associated with the U.S. Army's current experience with "virtual" digitization has been the false sense of control (or lack of control) it sometimes creates for the commander and his staff. During the BCR III experiment, the squadron commander ordered a troop commander to move a unit to a given location to block or shape enemy actions. When the ModSAF entity-level icons did not appear to react nearly instantaneously, the squadron commander frequently queried the unit-level commander to determine why he had not moved yet.

DTLOMS Implications

The level of commander visualization present in ModSAF can promote a false sense of control as well as frustration. The lesson learned is that near real-time reporting and display of unit or entity-level locations and status do not equate to a near real-time ability to move units around the real-world battlefield. Such things as organizational inertia, representing the time and staff actions needed to communicate intent, reconcile expectations, and resolve actions down through the various parts of the organization, as well as the time needed to physically move units over terrain, will remain real-world factors even with advanced sensor-fed battlefield information display capabilities. Command decision makers should be informed of these "tendencies" to expect immediate action or to micro-manage change, as part of the Army's future digital leader training initiatives.

Additional Insights

Cognitive Aids

To allow for varying levels of staff training and experience and to compensate for loss of higher level cognitive skills because of fatigue and sleep deprivation, future digitization should provide an intelligent agent-based capability that can aid the commander and staff in managing (tracking, fusing, assessing) key METT-TC-related issues and deltas over time to provide warning of developing situations for reaction or exploitation.

Abbreviated MDMP

Given white board capabilities, the battalion commander or S2 was able to receive a warning order from higher command, execute mission analysis, develop an intelligence preparation of the battlefield (IPB), create the concept of operation, select a single COA and "war game" it with troop commanders and other key staff, and direct the final scheme of maneuver, all within 25 minutes.

Flex Staffing

Given the flexibility afforded by the distributed capabilities of the advanced digitization and the level of MDMP abbreviation with the resulting extremely high OPTEMPO (approximately 30 minutes from warning order to COA execution initiation) on the one hand, and the varying levels of staff training and experience on the other, the commander should consider outsourcing key experienced staff (e.g., such as the deputy commander) to augment needy command and control cell staffs to improve processes and products critical to mission execution (i.e., current and future planning), while simultaneously providing needed OJT.

SECTION 4: FOCUS GROUP—TROOP COMMANDER INSIGHTS

As part of the ARL data collection efforts for BCR III, troop commanders were assembled immediately after the final AAR for the purpose of conducting focused discussions covering the technological and organizational structures employed. As a group, the troop commanders were asked what they liked and disliked about the ModSAF technology, what changes were evident in operating as a digitally supported organization and the implications of these changes, their general insights regarding the command process experienced, and the one change they would make in BCR III. A summary of the troop commander responses is presented next. Note that generally, the comments are very positive regarding the SA capabilities inherent in ModSAF-type battlefield visualization tools. Equally important, some of the constructive comments mirror several of the key ARL observation-based insights presented previously.

What did you like about the ModSAF hardware and software?

- Easy to use

- SA so effective that traditional graphical control measures no longer required to fight battle, synchronize forces, and so forth. Minimum possibility of fratricide. Complex passage of lines mission is simplified. Deconfliction problems experienced in real life are eliminated here.

- Company or platoon-level targeting easily directed using ModSAF

What didn't you like about the ModSAF hardware and software?

- Too many windows and menus to use. Need some tailorable "hot buttons" to decrease effort associated with navigating various applications to execute tasks.

• Need some type of "heads up" display where status summaries and fused data (SLANT reports) are always present for easy scanning and situation monitoring and assessment.

• Need two monitors because dual use splitting of ModSAF screen is not effective; reduction in size of battle picture combined with loss of resolution causes loss of SA.

• Requirement to go to separate "white board display" requires commanders to abort battle monitoring and control and thus breaks SA. Possibly execute white board mission analysis, COA, or war gaming directly overlaid on current operations map graphics because any new FRAGO scheme of maneuver would be in the same general AO.

• System should fuse and display information relative to commander's situation assessment and decision-making processes. For example, developing SLANT reports was difficult because the system did not allow tailored aggregation of data. Operator was forced to highlight icons, identify entities, and count "eaches." System should execute continuous monitoring and data fusion with status display tailorable to user information requirements and readily displayed on any ModSAF. Such capability would reduce much of the current command net traffic from the commander-deputy commander and other key staff (current operations logistics trackers, etc.).

What was different in changing from traditional (analog) operations to a digitized organization?

• In BCR III, the two scout platoons with UAV platforms are battalion or squadron assets answering to the squadron commander. In BCR, troops should have fire support team vehicles (FISTVs) with micro-UAVs. Real-life 2ACR is a heavy cavalry regiment with each second squadron troop having four organic company or troop-level FISTVs with dismountable FO elements. These are the "eyes" for the troop "shooters."

• Given capabilities provided by ModSAF, real-life troop-level staff elements would still be required (XO and First Sergeant, each in his or her own vehicle). In BCR III, the troop organization had the commander and XO and First Sergeant at the same display, which greatly hindered execution of all key tasks associated with troop operations (especially C^2 of G-troop with three maneuver and one mortar platoons).

General Process Insights

• SA eliminates the requirement to deconflict operations between platoons since all players can see each other and verbally coordinate and orchestrate movements, targeting, and so forth. Additionally, SA allows troops to monitor each other's sectors and to offer assistance and coordinate via net communication supported with visual monitoring.

- Troop-level virtual indirect weapon systems have no capability for local security (i.e., no supporting infantry or on-board crew-served heavy direct fire weapons). Supply trains have no local security capability, which forced these weapons to "run for cover" to avoid dismounted threat dropped into rear area. Additionally, when required to move rearward to cover an emerging situation, virtual missiles-in-a-box (MIBs) can drop their remotes (for later retrieval) with another supporting platoon's Bradley fighting vehicle (BFV). However, the non-line-of-sight (NLOS) system's tethered platforms had to be hauled back when NLOS units were required to relocate to the rear to engage rear area dismounted infantry threat.

- While the basic principles of combat operations do not change, SA minimizes need for traditional control measures. No five-paragraph orders need be developed or distributed. Troop-level commanders need only be provided general AO graphics and go with intent, task, purpose, and engagement criteria specified. Traditional regimental level generated control graphics (e.g., boundaries, engagement areas [EAs], named areas of interest [NAIs], contact points, etc.) are obsolete with ModSAF level of SA. The basic AO terrain graphics with 10 by 10 grids and unit objectives indicated are sufficient.

- Across various phases of the BCR III exercise, the same general AO was used for conducting day-to-day operations. For reasons unclear, the control graphics (e.g., EA names, phase line [PL] names, NAI numbers, etc.) changed from one phase to another almost on a daily basis. This changing of identifiers was confusing and placed heavy cognitive workload on the staff, especially when a current operation was continuing with one set of control graphics, while a 72-hour FRAGO was simultaneously issued or war gamed by white board with a completely different renamed set of control graphics covering the same AO.

What one thing would you change?

- Limit ModSAF-based visibility of battalion commander to one echelon down (i.e., troop-level "unit" icons, not troop-level "entity" icons) to minimize tendency to micro-manage troop-level operations.

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13. ABSTRACT *(Maximum 200 words)*

The Mounted Maneuver Battle Laboratory at Fort Knox, Kentucky, conducted the third battle command re-engineering experiment (BCR III), during the period of April 12 to April 30, 1999. This report describes the research efforts of the Human Research and Engineering (HRED) of the U.S. Army Research Laboratory (ARL) in support of BCR III. This research is a key element of the ARL 5-year science and technology objective (STO) IV.G.10: cognitive engineering of the digitized battlefield. For BCR III, ARL's efforts were centered on the virtual exercise in which a model future strike force variant organization with modular semi-automated forces (ModSAF)-based displays and advanced combat systems, performed battle command operations in order to gain a more robust understanding of the potential offered by these technological and organizational capabilities. Within the framework of the BCR III overarching issues, ARL's focal point was associated with the sub-issue question: What is the impact of situational awareness certainty and its cognitive effect on decision making, information request, and staff dynamics? This report cites the findings from the application of two ARL cognitive engineering-based research instruments, as well as observation-based insights and commanders' comments recorded during a focus group session held by ARL following the final after-action review. The two ARL instruments, the decision maker self-report profile (DMSRP) and the commander-centered decision environment inventory (C2DEI) focused on the various cognitive processes and environmental complexities associated with battle command decision making experienced during BCR III.

14. SUBJECT TERMS

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