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Collaborative Planning In Network-Enabled Co-Located and Distributed Environments

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A defining feature of Army transformation will be the development of digital communications capabilities to support distributed battle command. To support new equipment development a realistic planning task is required which can yield an objective planning performance benchmark score. The Reactive Planning Strategies Simulation (REPSS) presents a group planning and resource allocation task that can be used to generate a benchmark performance score. The present research investigated whether a benchmark REPSS performance score could be established that demonstrates sensitivity to manipulations in planning task conditions, and planning group skills. Twenty-two groups of seven Soldiers (commander and three two-person teams) performed the REPSS planning task after being assigned to either a co-located or distributed team planning condition. Results indicated that the planning performance success score for groups in the distributed condition fell below the benchmark score for groups in the co-located condition. Participant group member characteristics (rank, planning experience, and previous deployments) were significantly related to successful performance for groups in the distributed planning condition. These results provide evidence that the REPSS simulation can be applied to develop a benchmark estimate of performance against which manipulations in task conditions and planning group expertise can be compared.

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COLLABORATIVE PLANNING IN NETWORK-ENABLED CO-LOCATED AND DISTRIBUTED ENVIRONMENTS

EXECUTIVE SUMMARY

Research Requirement:

A defining feature of Army transformation will be the development of digital communications capabilities to support network-enabled distributed battle command. Previously battle command would be conducted with paper maps, acetate overlays, and voice radio networks. Future network-enabled battle command should rely heavily on new digital technology that supports text messaging, shared digital maps and graphic overlays, and the ability to reach out to access information in shared databases. To support new equipment development a realistic planning task is required which can yield an objective planning performance benchmark score. If this requirement is not met, the apparent performance superiority of one equipment design over another could simply be a function of the planning task chosen, characteristics of the planning environment, or skills that the test personnel bring to the task, rather than the inherent capabilities of the equipment. The Reactive Planning Strategies Simulation (REPSS) provides a potential solution to the requirement for a representative collaborative planning task that can be used to generate baseline and benchmark performance scores. The REPSS presents a group planning and resource allocation task which is set in the context of creating four weekly plans to acquire food, transportation, and security personnel to send out supply convoys as part of a hypothetical four-week humanitarian relief supply effort. The REPSS might serve as a solution to the requirement for an equipment design benchmark performance measure if it can demonstrate sensitivity to manipulations in planning task conditions, and planning group skills.

Procedure:

Groups of seven were formed. Each group had a commander and three two-person teams. Twenty-two groups of Soldiers comprised of officers and non-commissioned officers were assigned to either a control (co-located teams) or experimental (distributed teams) group collaborative planning task condition. Each group received an orientation briefing followed by self-paced automated training on the REPSS task and interface tools. Following this train-up, each group performed one 40-minute and three 20-minute problem solving sessions to create and send relief supply convoys to four towns for four weeks. An automated measure recorded each group's performance success in terms of the proportion of required relief supplies delivered to the towns.

Findings:

The results provide evidence that the REPSS simulation can be applied in controlled experimentation to develop benchmark estimates of performance against which manipulations in task conditions and planning group expertise are compared. A significant relationship was found between group planning condition and performance. Groups in the co-located condition

provided a significantly greater quantity of relief supplies than the groups in the distributed condition. Participant experience associated with rank differences was found to be significantly related to successful performance for groups performing in the distributed planning condition. Participant group experience in terms of previous group planning experience was also significantly related to successful performance in the REPSS exercise for groups performing in the distributed planning condition. Likewise, expertise gained through previous deployment experience showed a significant relationship to performance success for groups planning in the distributed condition. The REPSS was designed to present a challenging and realistic group planning task. Results provide evidence that the goal was achieved, as over 90% of participants responding to the REPSS survey reported that the planning exercise could be useful in command group training.

Utilization and Dissemination of Findings:

The REPSS provided a standard task requiring essential collaborative planning skills and procedures. The results yielded evidence that the REPSS simulation can be applied in controlled experimentation to develop a benchmark estimate of performance against which manipulations in task conditions and planning group expertise are compared. The findings provide support for the contention that equipment developers might use a simplified planning simulation such as REPSS to establish performance benchmark scores for the comparison of alternative collaborative planning equipment designs in the following capacities:

- Provide pre-test calibration of group planning skill (covariate to assess experiment performance). Currently the Army does not have assessment tools to estimate the proficiency level of groups used as test troops for new systems experimentation.

- Serve as a standardized scenario within battle lab experiments. New system development efforts typically suffer from the lack of a standardized scenario that can be applied across a variety of experiments.

- Serve as benchmark against which to test the delta (difference) in collective performance resulting from a technology insertion.

Command group planning exercises can be time consuming, expensive, and infrequently performed. The REPSS exercise might be employed as a half-day, inexpensive training event that could be conducted as frequently as required to maintain basic skills in collaborative planning. The results suggest that the REPSS is a useful research tool that objectively measures group problem-solving abilities. One opportunity for future REPSS research would involve assessing the impacts of feedback interventions (during and after the planning actions) on group planning performance success.

COLLABORATIVE PLANNING IN NETWORK-ENABLED CO-LOCATED AND DISTRIBUTED ENVIRONMENTS

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COLLABORATIVE PLANNING IN NETWORK-ENABLED CO-LOCATED AND DISTRIBUTED ENVIRONMENTS

Introduction

Research Need

A defining feature of Army transformation is the use of digital communications capabilities to support network-enabled planning by geographically distributed forces, and the delegation of planning responsibilities to lower echelons. The success of distributed planning will rely heavily on emerging digital communications technology. Research tools are needed to support the development of the emerging technology. Specifically, a standard collaborative planning task is needed that can provide baseline estimates of system performance for various operating conditions, and equipment designs. Likewise, tools are needed that can accurately assess the contribution of Soldier skills to system performance, to provide early estimates of personnel requirements. Once a baseline performance score is established for a planning condition, or an equipment design, the score can serve as a benchmark standard against which alternative conditions or equipment designs can be compared. The benchmark provides a measurement that can be used as a reference point in observations to compare alternative designs, processes, and personnel staffing arrangements.

The Reactive Planning Strategies Simulation (REPSS) was developed by the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) to meet the requirement for a research tool that objectively measures group problem-solving abilities, and might meet the requirement for a benchmark planning task. The REPSS presents a group planning and resource allocation task which is set in the context of a hypothetical humanitarian relief supply effort. The REPSS planning task requires essential planning skills and procedures, and incorporates a single “goodness of planning solution” score. Based on initial research (Sanders, Fultz, & Sharp, 2006) the REPSS appears to be a reliable simulation that can be used to benchmark planning group performance.

The REPSS might be useful as a benchmarking task for equipment design comparisons if it can demonstrate sensitivity to manipulations in planning task conditions, and planning group skills, both of which are likely to affect planning performance. The first goal was to investigate whether REPSS performance measures were sensitive to manipulations in planning task conditions. This was explored through the comparison of collaborative planning performance of groups assigned to distributed versus co-located planning conditions. The second goal was to investigate whether the REPSS performance measures were sensitive to manipulations in terms of planning group expertise. A key analysis involved the comparison of performance for high expertise groups composed entirely of officers with lower expertise groups composed of a mix of officer and non-commissioned officers (NCOs). For the convenience of the reader, a list of all acronyms is provided as Appendix A.

Background

REPSS overview. The REPSS is a software-driven simulation that incorporates a resource allocation task requiring collaborative group planning to arrive at a solution. The design of the REPSS builds on an approach for developing collaborative planning tasks and performance measures set forth by Lussier, Solick, and Keene (1992). The REPSS task presents a hypothetical humanitarian relief effort requiring a group composed of a commander and three functionally interdependent teams to send weekly relief supply convoys to four separate towns for four weeks. The REPSS task incorporates essential battle command skills requiring effective group communications, and the ability to adapt to change, as information must be shared between the commander and teams to build the planning solutions. Army doctrine prescribes the use of Mission, Enemy, Terrain, Troops, Time, Civilians (METT-TC) Factors in delineating the information essential to command and control, for commanders at all levels (Field Manual 3.0, Operations, Department of the Army, 2001). Specific tasks and functional relationships were incorporated into the REPSS system to exercise the METT-TC factors, making the REPSS exercise applicable across a broad range of current and future command and control (C2) support systems.

In the REPSS exercise, the senior officer is assigned as the group leader, who then divides the remaining members of the group into three teams (supply, transportation, and security). All Soldiers participate in a single three and one-half hour REPSS exercise which includes train-up, performance of the relief convoy task, and responding to exit surveys. Four simulated weekly relief convoys are planned and executed during the three and one-half hour exercise. Initial training is provided by a self-paced slide presentation.

In order to effectively solve the planning task, each team requires information originally provided to the other teams and the leader. The teams also depend on one another for intermediate products such as estimates and assessments. The analysis and scoring of REPSS solutions is done by automated measures built into the REPSS system. The REPSS exercise provides an overall estimate of the "goodness" of the group planning solution in terms of the quantity of humanitarian relief supplies delivered. Additional performance measures provide quantitative estimates of the groups' ability to synchronize the competing requirements of the supply, transportation, and security teams. The REPSS simulation is delivered on networked computers with one computer devoted to each position: commander, supply team, transportation team, and security team. A detailed description of the REPSS task may be found in Development of the Reactive Planning Strategies Simulation (REPSS) (Sanders, Fultz, & Sharp, 2006).

Planning challenges. The Army Technology Objective (ATO) titled Leader Adaptability states that high operational tempo, volatile mission demands, and serious resource constraints present challenges to leaders in the contemporary operational environment and the future network-enabled environments, which need to be integrated into the way we train our leaders (U.S. Army Research Institute for the Behavioral and Social Sciences, 2006). The REPSS incorporates a number of features which support the Leader Adaptability ATO research goals to include:

- High operational tempo: Planning groups have only 40 minutes to create and execute their plan for week one, and 20 minutes to adjust and execute a plan for each of the three following weeks.

- Adaptive planning: The planning groups are given inadequate funds to fully support the relief effort, requiring that they make tradeoffs between each of the teams to maximize the group result. A specific problem event is embedded in each of the four weeks requiring teams to adapt their plans in response.

- Networked environment tools: REPSS has been configured as both a traditional co-located command group planning environment and as a geographically distributed environment. Features include voice communications, text messaging, shared synchronization matrix, interactive map, and data files (digital newspapers) that participants must access to gather essential planning information.

Planning group conditions. A key issue facing the future force is that Army command groups must be capable of transitioning from the traditional face-to-face (co-located group) tactical operations center environment to collaborative planning across networked communication systems (distributed group). "Co-located groups" will be defined as groups whose members work as interdependent teams in a common physical space, whose interactions include face-to-face communications, as well as electronic communications (text messaging, and shared synchronization matrix). In contrast, "distributed groups" are interdependent teams, separated by some degree of physical space, whose interactions are mediated through electronic communications technology (voice radio, text messaging, and shared synchronization matrix). The impact of the transition to distributed operations is uncertain. Graetz, Kimble, Thompson, and Garloch (1997) suggest that computer-mediated communications associated with distributed group collaboration can offer both advantages and disadvantages compared to traditional co-located collaborative planning, which can impact the quality of planning performance:

- Advantages:
    - Compared to spoken statements, text-based messages are often composed and edited more carefully and received more quickly.
    - Text messages can be exchanged simultaneously, reducing the negative effects of participants having to wait their turn to speak.
    - Electronic communications can reduce the social anxiety experienced by group members, allowing them to contribute more freely than in co-located face-to-face communications.

- Disadvantages:
    - People may purposely omit statements normally offered during face-to-face conversations, such as brief utterances indicating agreement, attention, or understanding.
    - With regard to text messaging, simultaneous collaboration may lead to "attention blocking," where members of the group fail to attend to the messages of others while formulating and typing their own responses.

- Coordination problems may become particularly acute in decision-making tasks requiring the exchange and integration of information.
- Any difficulties collecting, structuring, or integrating information may elevate cognitive workload and increase the likelihood of errors.

Previous ARI research has suggested that significant differences exist in the way command group members perform collaborative planning based on whether they operate as a co-located or distributed group. However, in the absence of a common task with which to benchmark performance a direct comparison of performance success between planning conditions has not been possible. Results from four Future Combat System – Command and Control (FCS C2) experiments conducted by the Defense Advanced Research Projects Agency (DARPA) revealed that the co-located command group engaged in a fast-paced and flexible verbal exchange during simulated engagements (Lickteig, Sanders, Durlach, Lussier, & Carnahan, 2003). In sharp contrast, during experimentation with distributed command group members it was noted that communication was less frequent, and more closely resembled sequential staff briefings (Holden, et al., 2005). A similar relationship was noted in preliminary experimentation supporting the development of the REPSS. Given that there were only four command groups included in the preliminary REPSS evaluations, a statistical comparison across planning conditions could not be made. However, the transcription and analysis of verbal communications revealed that Soldiers performing the REPSS planning task as a co-located group exchanged 42% more verbal statements compared to Soldiers performing the same planning task as a distributed group (Sanders, Fultz, & Sharp, 2006). An unanswered question is whether additional experimental trials with REPSS would reveal that the performance success measure (percentage of required supplies delivered) is sensitive to the manipulation of planning conditions, co-located vs. distributed.

Planning group expertise. Successful mission command as described in Field Manual (FM) 1, The Army rests on the ability of commanders to convey the intent and concept of operations, provide resources adequate to accomplish the mission, and empower subordinates to make decisions while synchronizing their operations (Department of the Army, 2005, pp. 3-33). The REPSS task was developed to incorporate essential features of the Military Decision Making Process (MDMP) (Department of the Army, 2001) course of action development task, where a commander works with a supporting staff to generate a course of action and estimates of required resources. To develop essential planning expertise, MDMP staff skills training is included in the formal education of Army officers, and assignment to staff work is a common experience during career progression.

As the Army moves toward highly mobile and dispersed operations there will be a greater demand for planning and decision making at lower echelons. Missions formerly planned at battalion level may be accomplished through planning and execution at company level. This downward shift of mission responsibilities will place a corresponding requirement on lower echelon personnel to develop the skills and expertise required for successful planning. The initial research with REPSS employed a single expertise group, Army captains, as participants to control for the potential impact of expertise differences across co-located and distributed planning conditions (Sanders, Fultz, & Sharp, 2006). While the use of captains as participants might represent battalion staff planning expertise, an alternative expertise group roughly corresponding to company level planning could be formed by having a single captain supported by NCOs performing the REPSS planning task. The present research operationalized group rank as a continuous variable, the percentage of officers within each group, in assessing the relationship between rank and REPSS performance success.

Testing REPSS as a benchmark measurement. For REPSS to be useful as a battle command benchmark task it must demonstrate that its primary performance measure, percentage of required supplies delivered to the towns, is sensitive to manipulations of important collaborative planning variables. The present research systematically manipulated planning task conditions (co-located vs. distributed), and planning group expertise (percentage of the group members that are officers) to investigate whether reliable group planning performance benchmark scores could be established that would show significant differences between the manipulation conditions.

Hypothesis 1: The REPSS performance success score will indicate that groups performing in the co-located planning condition deliver a significantly higher percentage of the required food supplies compared to groups performing in the distributed condition.

Hypothesis 2: The REPSS performance success score will indicate that groups with a higher percentage of officers will deliver a higher percentage of the required food supplies compared to groups composed of fewer officers.

Support for Hypothesis 1 will provide evidence that the REPSS performance success measure is sensitive to differences in features of the planning conditions. That would provide evidence that the REPSS performance success measure could be used to benchmark the planning performance success rate for a specific equipment configuration. That would be used to compare alternative equipment design performance results against this benchmark standard to identify the payoff in improved performance associated with a design feature. In the present example the REPSS performance success score for the co-located group condition can be used as a benchmark against which to compare performance success in the distributed planning condition.

Support for Hypothesis 2 will provide evidence that the REPSS performance success measure is sensitive to differences in participant collaborative planning expertise. That would provide evidence that the REPSS performance success measure could be used to score the planning expertise level of test groups prior to employing them in the evaluation of alternative collaborative planning equipment designs. The group expertise score could then be used as a covariate in the analysis of the performance of competing equipment designs.

Method

Overview and Design

Groups of seven Soldiers were assigned to either the co-located group or distributed group condition. Groups were assigned to planning conditions so that there would be an equal number of groups assigned to the co-located and distributed planning conditions. An effort was also made to assign an equal number of high expertise groups composed entirely of officers and lower expertise groups composed of a mix of officer and NCOs to the two conditions. For each condition, the senior officer was assigned as the group leader, who then divided the remaining members of the group into three teams. A “co-located group” condition was created by having all seven members perform their planning tasks within a common room. A “distributed planning group” condition was created by assigning the commander, and each of the three two-man teams to separate rooms (four rooms total) which prevented any direct visual or verbal contact between the commander and teams. The seven members of each group acted as a commander and three two-person teams (supply, transportation, and security) performing the REPSS collaborative planning task. Each group received an orientation briefing followed by self-paced automated training on the REPSS task and interface tools. Following this train-up, each group performed one 40-minute and three 20-minute problem solving sessions to create and send relief supply convoys to four towns. Automated measures recorded each group’s performance success in terms of the quantity of relief supplies delivered to the towns. At the conclusion of the REPSS exercise the participants completed a demographic survey, and an experiment feedback survey. A detailed description of the REPSS apparatus and experimental method is provided in Sanders, Fultz, and Sharp (2006).

Participants

Participants for this research consisted of 142 U.S. Army officers and NCOs (one lieutenant colonel, seven majors, 76 captains, seven lieutenants, six warrant officers, and 44 NCOs) from Fort Knox, Kentucky, Fort Benning, Georgia, and Fort Huachuca, Arizona. The sample also included one Marine captain. Participants formed 22 collaborative planning groups. Twelve Soldiers scheduled for the experiments were unable to attend so that 14 groups performed with all seven members, five groups performed with six members, two groups performed with five members, and one group performed with four members. The difference in participant group size could potentially impact performance, and is addressed in the results section of the report.

Apparatus

The commander and each two-person team had networked computers with which to conduct their collaborative planning. The networked computers provided the capability to send and receive text messages, and provided two shared data matrices where the commander and teams could develop a weekly spending plan. The plan was entered via on-screen resource request forms. The reaction of the environment to the allocation of supplies each week was sent to the command group members in the form of pre-written text messages indicating losses and damage proportional to the shortfall in supplies delivered. Participants in the co-located condition could speak directly to each other to exchange information. Participants in the distributed condition were provided with hand-held single channel voice radio “walkie talkies” to support voice communications within the group. Fifteen groups located at Fort Knox used dual-display desk top computers to perform the REPSS tasks (11 distributed, 4 co-located). Seven groups total at Fort Huachuca and Fort Benning performed the REPSS exercise in the co-located planning condition using single display networked laptop computers (ARI portable minilab). When using the laptop computer the group members would have to access the map by opening a window on the display, rather than having the map displayed constantly on a separate display.

This difference in computer displays (dual-display desk top computers versus single display laptop computers) could potentially impact performance, and is addressed in the results section of the report.

The supply, transportation, and security teams each had a resource request window on their REPSS display. The spreadsheet design minimized calculation requirements by allowing participants to simply type in the quantity of assets they need. Figure 1 presents the transportation team resource request spreadsheet tool, where the team would enter the number and type of vehicles (either "armored five-ton" trucks, or unarmored "five-ton" trucks) requested for each town convoy, and the route. The spreadsheet automatically calculated the costs of the assets for each town route and displayed them in the "Total" column when the participant pressed the "Calculate" button. This feature facilitated the iterative adjustment of plans and fine tuning, based on group decisions. When a team had finished refining their plan for the week, they selected the "Submit" button to enter their plan and start the REPSS reaction process.

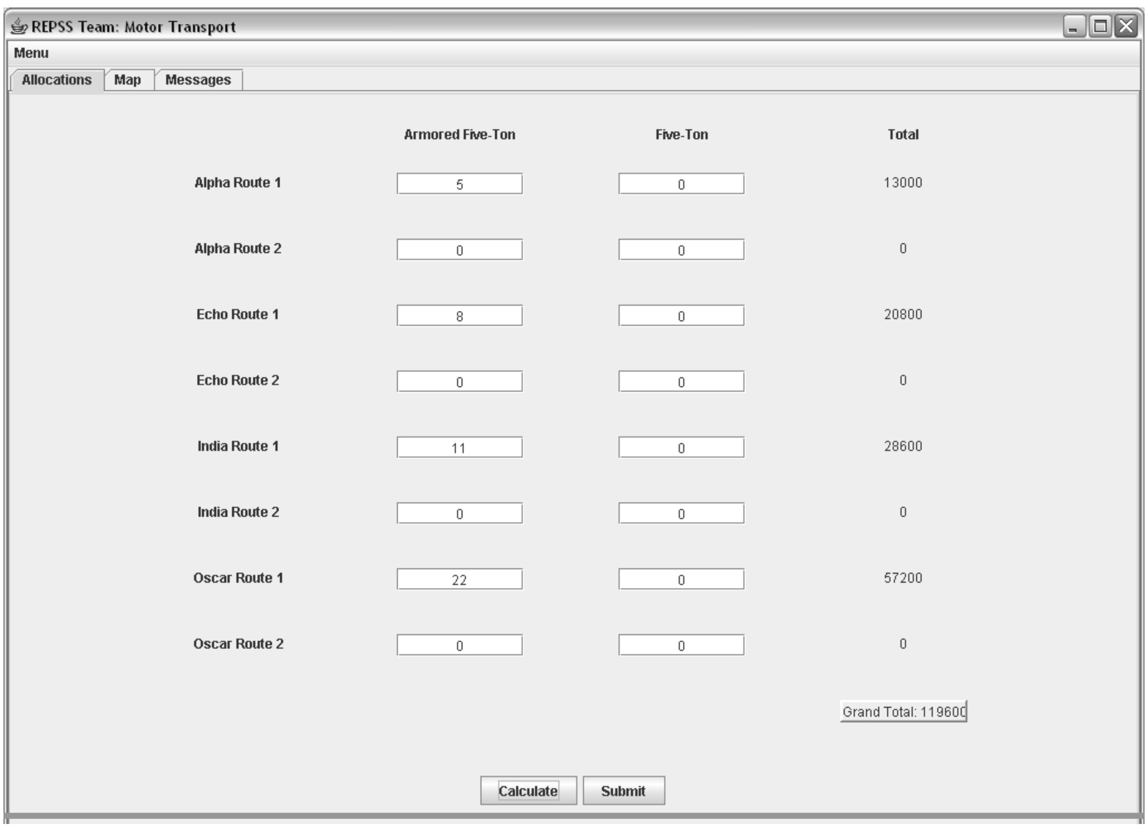

Figure 1. Transportation team resource request spreadsheet tool.

Collaboration matrix. The REPSS display provided two blank 14 by 11 cell matrices which were accessed by selecting a tab on the screen tool bar. The shared matrixes allowed any member of the group to enter information to support collaborative planning. In practice the matrices were used to display and organize information from each team to help define the planning problem, share data and team estimates, and document the weekly planning solutions.

Table 1 presents the collaboration matrix developed in pilot test trial 3 (Co-located Group), which includes the requirements for food supplies in the form of Humanitarian Supply Units (HSU), and estimates of citizen morale (CITMOR).

Table 1

Collaboration Matrix with Headings and Data Entered

	A	B	C	D	E	F	G	H	I	J	K
1	Town	Population	Threat Level	CITMOR	HSU	HSU Trucks	Security Trucks	Cost HSU	Ware house (min)	Cost Ware house min	Cost Ware house max
2	ALPHA	1600	Elevated	Low	16	8	16	192k	1	55k	130k
3	ECHO	2400	Guarded	Neutral	24	12	12	288k	2	110k	260k
4	INDIA	4000	Severe	Very Low	40	20	80	480k	2	110k	260k
5	OSCAR	6800	Elevated	Low	68	34	68	816k	4	220k	520k
6					148			1776k		495k	1170k
7											

Note: 14 columns were provided, but only A through K, and rows 1 through 7 are shown here.

Procedure

Training for participants. All Soldiers participated in a single three and one-half hour REPSS exercise. Training for participants consisted of a 10-minute overview briefing, followed by self-paced training at the commander and team workstations. The self-paced training consisted of a digital slide show which presented general instructions common to all participants, and also commander or team-specific instructions. The commander and team-specific instruction slides included a step-by-step orientation to REPSS interface, and an example of a data-entry task. A researcher observed the participant training and provided assistance as needed. Total time required for the overview briefing and self-paced training was approximately one hour. After the train-up the group began the REPSS exercise. Groups were told that they could take a five-minute break between each of the four planning sessions however, they were instructed not to discuss the exercise during the break. Most often groups elected not to take a break. On several occasions it was observed that group members in the distributed planning condition tried to use the five-minute break for a quick After Action Review, to share information and questions that they had difficulty conveying when separated. The research team strictly enforced the "No Discussion" constraint.

A typical exercise. In the REPSS exercise food supplies in the form of humanitarian supply units, referred to as "HSU" must be delivered by convoy from Camp Puller to each of the four towns (Alpha, Echo, India, and Oscar) across four weeks. An HSU is a container holding food and medical supplies sufficient to support the needs of 100 persons for one week. Each convoy is composed of supplies, convoy guards, and trucks. If a planning group fails to supply a town for one week, they cannot simply make up for this shortfall by providing twice the needed supplies the following week. Instructions to participants identified recommended levels of supply, transportation, and security assets that should be allocated to each convoy. However, each group is only provided approximately 75% of the funding that would be required to provide

100% of the recommended levels of support. The commander and three teams in each group must collaborate in developing a spending plan that maximizes the support that can be provided with the available funds. Figure 2 provides an overview of the REPSS humanitarian relief convoy task.

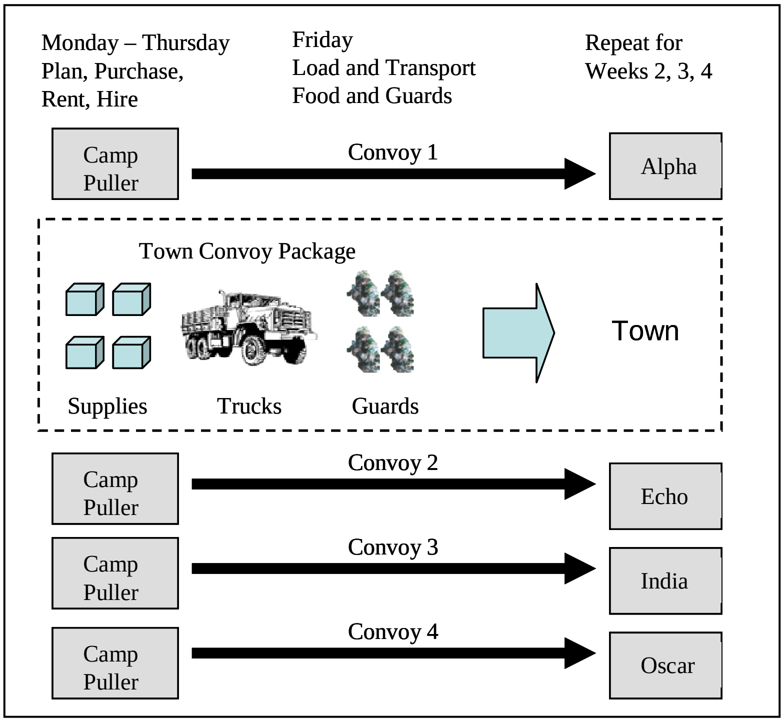

Figure 2. The REPSS convoy requirement for four separate convoys each week, for four weeks.

The commander should begin the planning process by identifying his strategy for allocating funds and establishing planning time limits. The supply team should first estimate the amount of HSU to transport to each town. The transportation team would use this information to determine how many trucks are needed for the HSU. The security team would then determine how many guards must be hired for the supply convoy and for town security and provide that information to the transportation team so that they can determine the number of trucks needed to transport the supply guards and town guards. Each team would calculate the total cost for their contribution and provide it to the commander. The commander would then calculate the total cost of the Week 1 relief effort and compare the cost to the total funds available for the four-week effort. Where the planned spending level falls above or below the level of funds the commander wishes to expend, the teams would have to adjust their spending. A great deal of the collaborative planning process involves having the commander and three teams develop a solution that matches expensive well-protected convoys to dangerous areas and less expensive lightly protected convoys to safer areas.

Measures Development

Overview. The REPSS provides a standard collaborative planning task that yields a single quantitative "goodness of planning solution" performance outcome score that was used to benchmark performance for alternative planning conditions and Soldier expertise. Five estimates of group expertise were developed from participant demographic survey data to assess the sensitivity of REPSS performance outcomes to the expertise of participant groups. One concern with hypothesis testing is that a hypothesis test does not evaluate the absolute size of a treatment effect. Effect size of comparisons was estimated using Cohen's *d*, which measures the mean difference in terms of the standard deviation. Using Cohen's *d* a mean difference less than 0.2 standard deviation is considered a small effect, greater than 0.5 is a medium effect, and a mean difference greater than 0.8 standard deviation is considered a large effect. Additional measures addressing plan synchronization, and adaptive planning were developed to support REPSS research. However, these measures are not reported in the body of the present report because they do not directly address the issues of baseline and benchmark planning performance success comparisons. The REPSS plan synchronization measure is presented in Appendix B. The REPSS adaptive planning measure is presented in Appendix C.

Planning Performance Success

Estimating planning performance success. The percentage of required supplies delivered (PRSD) score is automatically calculated by the REPSS and can be provided to participants as feedback immediately after each experiment. The estimate is the average percentage of supplies delivered across the four towns and four weeks, the average of the sixteen data points. The PRSD estimate has a potential weakness. A group that provides 100% of required supplies in Week 1 and Week 2, and nothing in Week 3 and Week 4 would receive the same score (50%) as a group that consistently delivers 50% of required supplies across all four weeks. Likewise, a group that provides 100% of required supplies to the two smaller towns, and zero to the two larger towns each week could achieve a score of 50%, while spending less funds than a group that provided a consistent 50% delivery rate equally to all four towns. For these reasons a transformation was applied where each of the sixteen PRSD scores were converted to its square root (SQRT) value and the sixteen values were summed to arrive at the PRSD SQRT score. By using the square root transformation the impact of extreme values of supply delivery on the total score is reduced, and consistency of delivery will result in a higher overall score. The PRSD SQRT score provides the single measure that can be used to benchmark planning performance success.

An alternative measure labeled "Adaptive Planning" was also considered which would provide an estimate of how well groups were able to adapt their planning each successive week, while controlling for the success or failure encountered in each prior week. J. M. Cortina (personal communication, August 4, 2006) has suggested that a comparison of percentage of required supplies delivered across weeks would not provide a good estimate of a groups' ability to adapt their plans successfully. Given that early planning performance constrains later performance, Week 1 planning performance must be more important than Week 2 performance, Week 2 is more important than Week 3, and Week 3 is more important than Week 4, thus the scores are not independent. A weighted average of the PRSD would thus provide a better estimate of group planning adaptability, where the weights reflect the differences in importance of each weekly plan. To generate the weights to apply to each weekly PRSD score the squared partial correlation between Week One and Week Two was calculated, while controlling for planning condition. This was repeated for Week Two and Week Three, and for Week Three and Week Four. The four calculated weekly weights were summed and the percentage contributed by each weekly weight was calculated so that all weights would sum to 100%. The resulting weights applied to each week's PRSD score were: Week 1 (0.26), Week 2 (0.25), Week 3 (0.25), and Week 4 (0.24). With these weights the transformation amounts to no more than weighting the weekly PRSD score by a constant (about .25), and results in scores ranging in value from .09 to .23 which cannot be interpreted directly in terms of amount of supplies delivered. Given these limitations it was decided to retain the PRSD SQRT score as the single measure of planning performance success.

Planning Group Expertise Estimates

A key goal was to investigate whether REPSS performance measures were sensitive to differences in terms of planning group expertise. All Soldiers completed a demographic survey which addressed: rank, time since last wargaming a course of action in a command group, experience in performing planning with the other members of the experimental group, previous deployments, and experience with commercial computer applications. Five estimates of group expertise were developed from the survey data for comparison against the PRSD SQRT performance success score.

Group rank. It was anticipated that officers might have more expertise than NCOs at collaborative planning tasks given their training and experience. The Group Rank measure was calculated as the percentage of officers within each participant group. Two types of participant groups were requested, Officer Groups (all seven positions filled by officers), and NCO Groups (one captain and six NCOs E7 or above). Due to troop support constraints it was not always possible to have the exact rank group composition requested. The 22 REPSS exercises were conducted with 15 groups composed of four or more officers, and seven groups composed of four or more NCOs with a captain serving as group commander.

Group planning experience. Recent group planning experience is likely to contribute to planning expertise and success on the REPSS task. The demographic survey included the question "How long has it been since you last participated in a group planning session?" Participant responses were scored to indicate those who had participated in group planning in the last year, and those who had not. The Group Planning Experience score is the percentage of participants in a group who have participated in group planning in the last year.

Group cohesion. Groups composed of Soldiers who have experience planning together could be expected to do better on the REPSS planning task compared to groups where the members don't know each other. A question in the demographic survey asked "How many members of your experiment group have you worked with before on planning tasks?" The Group Cohesion score is the average of the group member responses on this survey item, the average number of people in the group that the members have planned with before.

Group deployment experience. Soldiers who have been deployed may have gained experience in areas such as communicating and rapid decision making that would help them in accomplishing the REPPS planning tasks. A demographic survey question asked participants to identify whether they had been deployed. The Deployment Experience score is the percentage of participants in a group who had been previously deployed. The question gathering this data was added after the initial four trials. Data are available for Soldiers from the 18 subsequent trials.

Group computer experience. Expertise in using computers could contribute to success in performing the REPSS planning tasks. It should be noted that the REPSS was designed to be very simple to use, so that computer skills would not be required for successful performance. A question in the demographic survey asked participants to indicate the years of experience they have using commercial computer applications. The Group Computer Experience score is the average number of years of computer experience for the members of the group.

Results

The results provide evidence that the REPSS simulation can be applied in controlled experimentation to develop a baseline estimate of performance which becomes the benchmark against which manipulations in task conditions and planning group expertise are compared. They provide support for the contention that equipment developers might use a simplified planning simulation such as REPSS to establish performance benchmark scores for the comparison of alternative collaborative planning equipment designs.

REPSS Sensitivity to Planning Condition Manipulations

Planning success by planning condition. The key assessment involves the comparison of the co-located condition REPSS performance benchmark score against the performance score attained for the distributed planning condition. An independent-samples *t* test comparing the PRSD SQRT score for the co-located and distributed conditions revealed a significant difference between the two groups ($t(20) = 2.378$, $p < .05$ [1 tailed test]). The Cohen's statistic $d = 1.02$, provided additional evidence of a large effect size, providing evidence of a difference between the planning conditions. The performance mean for the co-located planning condition (benchmark score) was greater ($m = 11.5$, $sd = 1.76$) than the mean for the distributed condition ($m = 9.5$, $sd = 2.13$). This finding provided some evidence that the PRSD SQRT score was sensitive to the manipulation of planning conditions. The PRSD SQRT score for the co-located condition might prove useful as a performance benchmark against which a performance decrement for the distributed planning condition can be detected.

As mentioned previously, 12 Soldiers scheduled for the experiments were unable to attend so that 14 groups performed with all seven members, five groups performed with six members, two groups performed with five members, and one group performed with four members. An independent samples *t* test was conducted, and indicated that the average number of Soldiers in the co-located planning condition ($m = 6.55$, $sd = .82$) and the distributed condition ($m = 6.27$, $sd = 1.00$) did not differ significantly ($t(20) = .459$, $p > .10$ [2 tailed test]). The smallest participant group consisted of only four Soldiers. An independent samples *t* test was conducted, indicating that the PRSD SQRT performance score for the 4-Soldier group (10.39, $sd = 0$) and all other groups (10.50, $sd = 2.21$) did not differ significantly ($t(20) = .963$, $p > .10$ [2 tailed test]). Two-person teams will continue to be used in future experiments, as a great deal of within-team discussions occurred which should impact the quality of solutions.

Another potential confounding variable that needed to be explored involves the different computer displays used (dual-display desk top computers versus single display laptop computers) which could potentially impact performance. An independent-samples *t* test comparing the PRSD SQRT performance success scores for co-located groups using desktop versus laptop computers did not find a significant difference between the means of the two groups ($t(20) = -1.54$, $p > .05$). The mean for the groups using laptop computers was not significantly lower ($m = 10.02$, $sd = 2.13$) than the mean of the groups using desktop computers ($m = 11.50$, $sd = 2.00$). This finding fails to provide evidence that performance differences associated with the use of the single laptop display contributed to observed differences in HSU delivery performance.

REPSS Sensitivity to Differences in Planning Group Expertise

Estimates of planning group expertise obtained with the REPSS demographic survey were compared to the PRSD SQRT score. Significant results provided evidence that the REPSS performance measure was sensitive to differences in planning group expertise, and that benchmarks might be established for these expertise factors corresponding to desired planning performance levels. Prior to analyzing the data separately, it is important to know that co-located and distributed groups did not differ significantly in expertise from the outset of this experiment. The results of independent-samples *t* tests reveal that for the five skill variables, the groups performing in the co-located condition differ significantly compared to groups performing in the distributed condition on only the Previously of Group Previously Deployed demographic score. The percentage of Soldiers who had previously been deployed was significantly greater ($t(16) = 1.79$, $p < .10$ [2 tailed test]) for the co-located planning condition ($m = .92$, $sd = .11$) compared to the distributed condition ($m = .79$, $sd = .19$). The rate of previous deployment is high for groups in both planning conditions, but the difference is significant. As reported in Table 2, the Percentage of Group Previously Deployed measure is significantly related to performance success only for the Distributed group.

An exploratory series of correlational analyses were performed to examine whether group expertise factors contributed to performance success (see Table 2). Separate analyses are presented for co-located and distributed groups as different skill demands might be present in the two conditions. Given that the sample sizes were small ($n = 11$) in both conditions, results should be interpreted with caution and are primarily reported here for exploratory purposes and to stimulate future research ideas. The present research intentionally included both officers and NCOs to provide a range of rank, planning experience, and computer experience. As might be expected, some of these expertise factors were found to be correlated. Evaluating the data from all 22 groups, the Group Rank measure was significantly related to Percent Group Planned in Last 12 Months ($r = .67$, $p < .01$), and Years of Computer Experience ($r = .70$, $p < .01$).

Group rank. Officers might bring formally trained planning skills and experience to the REPSS task that contribute to performance success, while NCOs could possess these skills to a lesser extent. As shown in Table 2, a Pearson correlation was calculated to estimate the relationship between the percentage of officers in each group and the PRSD SQRT score for both the co-located and distributed group conditions. The percentage of officers and PRSD SQRT score were not significantly correlated for the co-located condition. A moderate significant correlation was found for the distributed condition ($r(9) = .45$, $p < .10$), which provides some evidence that rank related proficiency contributed to observed differences in HSU delivery performance in the distributed condition. One concern was that the participant rank might not

Table 2

Expertise Indicator Mean, and Correlation with PRSD SQRT Performance Score

Expertise Indicator	Co-located M	Co-located r	Distributed M	Distributed r
Group Rank (percent officers in group)	.81	(-.20)	.56	(.45)*
Percent Group Planned in Last 12 Months	.65	(-.27)	.55	(.58)**
Cohesion (average number of group members known)	.71	(.09)	1.11	(-.01)
Percent of Group Previously Deployed	.92	(-.20)	.79	(.67)**
Years of Computer Experience	4.03	(-.40)	3.83	(.36)

Notes. * $p<.10$, ** $p<.05$ (all significance tests are 1-tailed)

have been equally allocated across conditions, and that this difference could contribute to the higher PRSD SQRT score for the co-located planning condition. A Pearson correlation was calculated to estimate the relationship between planning condition and PRSD SQRT scores, controlling for Group Rank. A moderate negative correlation was found ($r(19) = -.41$, $p < .05$), which provides evidence that the co-located condition was superior to the distributed condition in terms of the PRSD SQRT planning success score even when controlling for the potential contribution of group member rank.

Group planning experience. It was anticipated that group planning experience could have a positive impact on the collaborative planning task success. An estimate of group planning experience was calculated as the percentage of group members who had conducted group planning in the past year. Values on this group expertise estimate ranged from .00 (no member of the group had engaged in group planning in the last 12 months) to 1.00 (all members had engaged in group planning, ($m = .42$, $sd = .34$). As shown in Table 2, a Pearson correlation was calculated to estimate the relationship between the Group Planning Experience score and the PRSD SQRT score for both the co-located and distributed group conditions. No significant correlation was found for the co-located condition. In contrast, a significant positive correlation was found for the distributed condition ($r(9) = .58$, $p < .05$). The findings provided some evidence that for groups performing as distributed teams, recent experience with similar planning tasks contributed to PRSD SQRT planning success.

Group cohesion. If team members have planned together previously they might be better able to perform the REPSS task requiring collaboration skills. The Group Cohesion score is the average number of people in the group who have planned together before. The values for the Group Cohesion score were $m = 1.02$, $sd = 1.09$. A Pearson correlation was calculated to estimate the relationship between the Group Cohesion score and the PRSD SQRT score for both the co-located and distributed group conditions. There was no significant correlation between Group Cohesion and the PRSD SQRT for both the co-located and distributed conditions. These findings failed to provide evidence that proficiency gained through having worked with group members before on similar tasks contributed to observed differences in PRSD SQRT scores.

Group deployment experience. The Group Deployment Experience score documents the percentage of participants in each planning group who have previously been deployed. Values on this measure ranged from .57 (four members out of seven had been deployed) to 1.00 (all members had been deployed) (m = .78, sd = .18). As shown in Table 2, a Pearson correlation was calculated to estimate the relationship between the deployment experience and the PRSD SQRT score for both the co-located and distributed group conditions. No significant correlation was found for the co-located condition. In contrast, a significant correlation was found for the distributed condition ($r(9) = .67$, $p < .05$). These findings provided some preliminary evidence that groups with more members who have been deployed tend to be more successful when required to perform as distributed teams.

Group computer experience. It was desired that the REPSS planning task would be sensitive to essential collaborative planning skills and not influenced by extraneous factors such as general computer skills proficiency. One question on the Demographic Survey asked participants to indicate their years of experience with commercial computer applications. The Group Computer Experience score is the average number of years of computer experience for the members of the group. The mean value for the Group Computer Experience score was m = 3.92, sd = 1.37 years. No significant correlations were found between the PRSD SQRT score and Group Computer Experience for either the co-located condition or distributed condition. These findings failed to provide evidence that computer skills proficiency contributed to observed differences in PRSD SQRT scores. This is consistent with the REPSS design goal of presenting a highly simplified task, an easy to use spreadsheet interface, and very simple map tools, so that computer skills would not be a contributing factor to planning performance success.

Potential factors contributing to planning performance success. Observations of the behavior exhibited by high performing groups suggest that differences in planning success might be attributable in part to several leader behaviors and the effective leveraging of planning tool capabilities. Given that commander expertise could be a critical factor in group planning success, it is important to identify whether commander expertise was equivalent between co-located and distributed groups. The results of independent-samples *t* tests reveal no significant differences between co-located and distributed group commander scores on the five skill variables (rank, planning experience in last 12 months, previous deployment, years of commercial computer experience). These results fail to provide evidence that differences in Commander skills contribute to the differences in performance seen between the two planning conditions.

It appears that collaborative planning was more successful when the commander provided an early concept for allocating funds, set (and enforced) specific planning time limits, and required that teams use the synchronization matrix to share information. By provided an early rough spending plan, commanders allowed teams to calculate early “ball-park” solutions to their resource needs which left more time for fine-tuning the final plan. Time management appeared to be a challenge. Many groups ran out of time during the planning process and had to implement poorly synchronized solutions in order to meet the deadline. In general, successful groups quickly populated the synchronization matrix with the key data and information requirements of each team. The use of the synchronization matrix allowed for the simultaneous rapid and accurate sharing of information and allowed the commander to monitor the progress of the separate teams. For both distributed and co-located groups it appeared that failure to use the synchronization matrix led to slower planning progress, with sequential question and answer exchanges that interrupted team planning, and required teams to repeatedly check to make sure that they had the most current version of the planning numbers. Instances were noted where participants made severe errors when verbally communicating numerical estimates, transposing numbers and making order-of-magnitude mistakes (e.g., reading "5000" but saying "500").

Feedback from participants. The REPSS was designed to present an efficient half-day exercise hosted on commercial computers with automated training and performance feedback that could support both new equipment experimentation, as well as basic collaborative planning skills training. Results from the Demographic Survey provided evidence that the REPSS exercise tapped into planning skills that should be addressed in Army training. When asked about the training potential of REPSS, 120 of 133 participants (over 90%) who responded to the survey question reported that the planning exercise could be useful in command group training.

Discussion

The REPSS was developed by ARI to meet the requirement for a research tool that objectively measures group problem-solving abilities. The REPSS provides a standard task requiring essential collaborative planning skills and procedures. The results provide evidence that the REPSS simulation can be applied in controlled experimentation to develop a baseline estimate of performance which becomes the benchmark against which manipulations in task conditions and planning group expertise are compared. This provides support for the contention that equipment developers might use a simplified planning simulation such as REPSS to establish performance benchmark scores for the comparison of alternative collaborative planning equipment designs.

The key assessment involved the comparison of the co-located condition REPSS performance benchmark score against the performance score attained in the distributed planning condition. A statistically significant difference was found for the comparison, suggesting that groups performing in the co-located condition were better able to perform the collaborative planning tasks, delivering a greater percentage of the required supplies. Another way of viewing the results is to say that performance by groups in the distributed planning condition falls below the benchmark performance score achieved by groups performing in the co-located condition. The finding provides evidence that the REPSS PRSD SQRT planning performance measure is sensitive to the manipulation of planning conditions.

The results also provide some evidence that three planning group expertise factors were related to successful performance on the REPSS exercise. The rank of the group members (percentage of officers in the group) showed a significant and moderate relationship with performance success for groups planning in the distributed condition. This suggests that the planning skills associated with officer expertise do contribute to observed planning performance success when teams must collaborate through computer-mediated communications. Group planning experience showed a significant and moderately strong relationship to performance success for groups planning in the distributed condition. Expertise gained through previous deployment experience also showed a significant and moderately strong relationship to performance success for groups planning in the distributed condition. This suggests that communication or planning skills developed in deployments contributed to success in the collaborative REPSS planning tasks. These findings provide evidence that the REPSS could have utility as a research tool for investigating the contributions of specific types of expertise to collaborative group planning performance. Again the moderately strong relationship found between expertise factors and the PRSD SQRT performance success measure suggests that with additional trials statistically significant relationships might be demonstrated.

Taken together, these results suggest that the REPSS might be a useful tool for development of baseline estimates of system performance, and for identifying the contribution of Soldier skills to system performance. With regard to Hypothesis 1, the findings do provide some evidence matching the prediction that groups performing in the co-located planning condition would deliver more food supplies compared to groups performing in the distributed condition. The finding supports the use of REPSS to benchmark the planning performance success rate for a specific equipment configurations, to identify the payoff in improved performance associated with design changes. Likewise, the REPSS might be used as a standard task for scoring the planning expertise level of test groups in order to factor out the contribution of test group expertise to observed performance.

With regard to Hypothesis 2, the findings provide partial evidence supporting the prediction that groups with a higher percentage of officers would deliver a higher percentage of food supplies compared to groups with fewer officers. Differences in group skills (group rank, recent planning experience, cohesion, prior deployments, and computer experience) were not a factor contributing to collaborative planning success for face-to-face co-located groups. However, for groups performing in the distributed condition, three group skill factors (group rank, recent planning experience, prior deployments) were related to higher levels of achievement, suggesting that the move to distributed collaboration might present additional skill demands beyond those required in co-located planning. These findings provide evidence that the measures of group expertise used in the REPSS research are related to essential collaborative planning skills, and might be used to factor out the contribution of test group expertise to observed performance.

Future ARI research efforts will likely involve investigating the potential for transitioning REPSS to support the development of new communications and collaborative planning technology and opportunities to employ REPSS in a training development role. The REPSS provides a realistic collaborative planning tool that might be used to support future C2 system development efforts in the following capacities:

- Pre-test calibration of group planning skill (covariate to assess experiment performance). Currently the Army does not have assessment tools to estimate the proficiency level of groups used as test troops for new systems experimentation. Performance observed in new equipment trials could be attributable to the capabilities of the test troops as easily as to the capabilities of the equipment. The REPSS can be used as a pre-test calibration tool to provide an estimate of group planning skills, which could then be used as a covariate in identifying the relative contributions of planning skill and equipment design to observed performance.

- Standardized scenario within battle lab experiment. New systems development efforts typically suffer from the lack of a standardized scenario that can be applied across a variety of experiments. Often a different scenario is played out for each new experimentation effort, so that there is no common metric for comparison across experimentation efforts. The REPSS provides a standardized scenario, with automated train-up and performance assessment capabilities, with performance scores from 22 Soldier planning groups that can stimulate collaborative planning across a variety of technologies.

- Serve as benchmark against which to test the difference (delta) in collective performance resulting from a technology insertion.

While technological innovations are intended to enhance system performance, they can also present new demands that can actually hinder task accomplishment. Development of future C2 capabilities will include the investigation of a vast array of technology designs which need to be systematically evaluated to identify their contribution to group planning performance. The REPSS exercise can serve as an efficient, baseline, group planning stimulation tool for use with new equipment evaluations allowing designers to systematically assess the benefits of selective technology insertions. Here, the REPSS exercise might be presented on a laptop computer at each new equipment node. The REPSS exercise could serve as a stimulus for information that must be exchanged across the new equipment, as well as providing an automated performance scoring capability. Running a REPSS exercise first to baseline performance with a system, and then running the exercise again with a new technology insertion, can provide an empirical estimate of the planning performance difference (delta) associated with the introduction of the new technology.

- Post-test assessment of group planning skill (delta on collaborative planning performance). The use of pre- and post- training REPSS assessments of group planning skill could be employed to assess the impact of training on group collaborative planning performance.

- The REPSS should be able to be expanded from Combat Support to Combat Arms and Combat Service Support scenarios. Currently the REPSS scenario presents a simplified humanitarian relief Combat Service Support operation. This scenario actually represents a very thin “skin” of text description layered over a group collaborative planning framework. By changing the text description of the scenario, and the text of the message traffic, the REPSS exercise could be modified to present a broad range of planning situations. The planning required might be equally representative of the challenges facing Combat Arms planners in a platoon-level mounted combat patrol, or Combat Support planners providing Military Intelligence support.

The REPSS exercise might also be employed as a half-day, inexpensive training event that could be conducted as frequently as required to maintain basic skills in collaborative planning. If desired, the exercise could also be used as a means to train unit-specific tactics, techniques, and procedures for collaborative planning. As previously noted, the REPSS exercise was designed to incorporate METT-TC factors into the tasks participants perform. The REPSS exercise addresses key skills that should be a prerequisite for success in any planning task. Time management, critical thinking, and communication skills should be essential to all planning tasks, and these skills might be developed with a simplified resource allocation task, rather than requiring a full fidelity exercise requiring extensive doctrinal and subject matter knowledge. Automated performance reports serve as unobtrusive during-action review aids, and support post-exercise After Action Reviews. The REPSS simulation serves to demonstrate techniques that can be used to create a low cost training for collaborative planning.

One opportunity for future REPSS research would involve assessing the impacts of feedback interventions (during and after the planning actions) on group planning performance success. The analysis and scoring of REPSS solutions is performed by automated measures built into the REPSS software, so that an overall planning performance success score and a record of team planning decisions are available after each of the four weekly convoy plans are submitted by the group. Rather than simply focusing on identifying planning coordination mistakes, the feedback interventions could address how well the planning group integrates METT-TC doctrinal considerations into their planning solutions.

The REPSS was developed by the ARI to be a tool that objectively measured group problem-solving abilities, and can serve as a benchmark planning task. The REPSS task incorporates essential battle command skills requiring effective group interpersonal communications, the ability to adapt to change, and a focus on METT-TC factors influencing decision making. Results suggest that the REPSS might meet the requirement for a tool to support the development of the emerging technology, as it demonstrates sensitivity to manipulations in planning task conditions, and planning group skills, both of which are critical factors impacting planning performance.

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Appendix A

Acronyms

ARI	U.S. Army Research Institute for the Behavioral and Social Sciences
ATO	Army Technology Objective
C2	Command and Control
CITMOR	Citizen Morale
DARPA	Defense Advanced Research Projects Agency
FCS C2	Future Combat Systems - Command and Control
FM	Field Manual
HSU	Humanitarian Supply Unit
METT-TC	Mission, Enemy, Terrain, Troops, Time, Civilians
MDMP	Military Decision Making Process
NCO	Non Commissioned Officer
PRSD SQRT	Percentage Required Supplies Delivered, Square Root
REPSS	Reactive Planning Strategies Simulation

Appendix B

Plan Synchronization

Plan Synchronization Measurement

The REPSS weekly spending data provide estimates of how well the group is able to synchronize the spending plans for the supply, transportation, and security teams. The group plan is considered to be synchronized when all HSU purchased and security guards hired can be transported with the trucks rented, with no deficiency or excess carrying capacity. A perfect match would yield a score of 100%, while any percentage of trucks under or over the required number represents a waste of assets, and a failure of the teams to synchronize their plans (10% too few, and 10% too many would both yield a synchronization score of 90%). The scores reflect the ability of a planning group to create a synchronized plan in 40 minutes for Week 1. The synchronization score also reflects the ability of a group to adjust their plan in 20 minutes for Weeks 2-4 in response to changing environmental conditions, and decreasing funds. One advantage of the synchronization estimate is that it provides an estimate of collaborative planning proficiency even if very few funds are available. Caution must be exercised in comparing weekly mean synchronization scores, particularly for later weeks, as only a few highly successful groups might be contributing to the mean. It should be noted that plan synchronization is a necessary, but not sufficient, condition for performance success. Groups will not be successful if their individual supply, transportation, and security team plans are not synchronized. However, the groups can produce bad plans that are perfectly synchronized, which will also result in poor performance. The REPSS software automatically calculates a plan synchronization score for each of the four towns and each of the four weeks. The scores can be provided to participants as feedback immediately after each weekly planning session. The synchronization scores can be used to quickly identify where problems occur in group planning, and support the detailed analysis of behaviors contributing to observed performance.

The group planning synchronization score provides an estimate of how effectively a group can coordinate the purchase of supply, transportation, and security resources required for each town, for each of the four weeks. A score of 100% indicates a perfect match between the carrying capacity of trucks rented and the amount of food and security guards to be transported. The Plan Synchronization scores ranged in value from .39 to .95, $m = .76$, $sd = .13$. The plan synchronization scores will only have value in assessing group performance if they are a contributing factor to performance outcomes. A Pearson correlation was calculated to estimate the relationship between group plan synchronization scores and the Percentage of Required Supplies Delivered – Square Root (PRSD SQRT) scores. A strong positive correlation was found ($r(20) = .65$, $p < .01$), indicating a significant linear relationship between the two variables. This finding provides evidence that groups with more highly synchronized plans deliver higher rates of HSU, which supports the use of synchronization scores in investigating group planning performance.

The examination of plan synchronization scores provides a useful approach to identifying group planning behavior associated with performance problems. Detailed plan synchronization information was collected beginning with Group 5, providing information for a total of 18 groups. There are 16 synchronization scores potentially available for each group (four towns X four weeks) though several groups ran out of funds and do not have Week 4 plan synchronization scores. A review was conducted to identify group planning actions that resulted in low synchronization scores. To limit the number of cases reviewed it was decided to examine scores that fell two standard deviations below the mean of all synchronization scores. With $m = .76$, and $sd = .13$, the criteria for review was set at a synchronization score of .50 or lower. Table 1 below describes low synchronization score cases, by group planning condition. Where possible, the current (low) synchronization score is compared with the previous week's score (Synch Previous Week/Current). This comparison is very helpful in identifying situations where a group performed well in one week, but was unable to adapt their plan in response to change in a subsequent week.

Plan Synchronization Results

For the groups performing in the co-located condition, eight problems were identified. With four of the seven problems, groups did well in Week 1 planning, but failed to coordinate a major change in their spending plan for Week 2 between the three teams. In three instances a poorly coordinated plan was followed by a second poorly coordinated plan, suggesting an inability to create a successful plan, rather than an inability to adapt an existing plan in response to changing events. One low synchronization score occurred where a convoy consisted of only one truck carrying two HSU. This left the single convoy truck half empty, but did not actually represent a synchronization problem.

For the groups performing in the distributed condition, nine problems were identified. Two problems (Group 11 and Group 20) reflect a knowledge failure, where the participant fails to understand that one truck can carry four HSU. Three procedure problems are evident, where a group either failed to submit their plan, or submitted only a partial plan. This type of problem did not occur for the co-located groups where the Commander could turn in his chair to see whether each team's plan included all four towns, and that the plan was submitted on time. With four of the ten problems, the groups did well in Week 1 planning, but failed to coordinate a major change in their spending plan for Week 2 between the three teams.

Discussion

The Plan Synchronization measure demonstrated sensitivity to planning condition manipulations, and a significant shared linear relationship with the HSU delivery scores. The Plan Synchronization scores were used to focus on a select sample of problem situations, identifying the types of performance problems that led to poor delivery of relief supplies.

Table 1

Plan Synchronization Problem Review

Group	Week/ Town	Synch Score (previous/ current week)	Problem Description
CO-LOCATED PLANNING CONDITION			
7	2 Alpha	.86/.30	Good previous week, then trucks cut by half but supply and security teams stayed with previous week's planning numbers.
7	2 Echo	.94/.40	Good previous week, then cut trucks by 63% without changing HSU or security guards.
7	2 Oscar	.92/.43	Good previous week, then increased trucks by 56% without changing HSU or security guards.
7	3 Alpha	.31/.19	Poor previous week, already had too many trucks, then dropped HSU without reducing trucks proportionally.
7	3 Echo	.41/.26	Poor previous week, too many trucks, then cut HSU without reducing trucks proportionally.
7	3 Oscar	.43/.31	Poor previous week, too many trucks, then cut HSU 40% without reducing trucks proportionally.
13	2 Oscar	1.0/.41	Great previous week, then doubled HSU without increasing trucks proportionally. Cut security assets by over half.
16	3 Alpha	.60/.50	Low synchronization scores both Week 2 and 3 reflect very low HSU quantities. Week 3 convoy has only two HSUs and one truck.
DISTRIBUTED PLANNING CONDITION			
Group	Week/ Town	Synch Score (previous/ current week)	Problem Description
5	2 All towns	.85/0	Good previous week, then procedure problem where HSU and guards requested, but no request submitted by transportation team.
9	2 Alpha	.83/.36	Good previous week, then added 10 trucks that were not needed while supply team reduced its request by one HSU.
9	2 Oscar	.99/.38	Great previous week, then supply team cut HSU by half, and transportation cut trucks 75%. Result was too few trucks.
9	4 Alpha	.80/.36	Good previous week, then doubled HSU and security guards request without proportional increase in trucks.
10	1 EIO	NA/0	Week 1 procedure problem. HSU and guards acquired for all towns, but trucks only acquired for town Alpha.
10	3 Echo	1.00/.34	Great previous week, then supply team cut HSU request by half, but transportation team doubled their request for trucks.
11	1 Alpha	NA/.18	Week 1 knowledge problem. Transportation needed six trucks but only rented one. May not understand one truck carries four HSU.
11	1 EIO	NA/0	Week 1 procedure problem. Transportation and security provided assets for Alpha only, supply team purchased HSU for all towns.
20	1 and 2 all towns	.40/.42	Both weeks transportation team provided one truck per HSU, not one truck per four HSU as required.

Note: The term NA indicates that for Week 1 problems there is no previous week synchronization score for comparison. EIO = Towns Echo, India, and Oscar.

Appendix C

Adaptive Planning

Estimates of Adaptive Planning Performance

Adaptive planning problem manipulations. The Army training objective calls for training that fosters adaptive leaders, able to deal with a rapidly changing environment. In response, the REPSS has embedded problem events into the exercise that require the planning group to collaborate and modify their plans. One advantage in embedding problems is that it provides a limited number of specific events which can be scored to identify where a group successfully adapts to a specific event requirement. The four planning problems events (one for each week) require each group to gather, exchange, and integrate important information into each weekly plan. Separate pieces of information identifying a problem situation were provided in text messages, town newspapers, and with information that could be accessed from the team maps. A group that shared the information, recognized the problem, and responded would allocate their resources correctly in response to the change. Making the correct decision for each problem event results in cost savings and damage avoidance. The REPSS simulation records the group purchase request form information necessary to identify whether a group has successfully responded to the problem situation (ex. convoy route selected for a town, type of supply trucks rented, the types of guards hired, and the quantity of supplies allocated across the towns each week). The four embedded problem events were introduced into the REPSS task beginning with group 9, so that data are available for a total of 14 groups (seven co-located, and seven distributed). The weekly problem events are as follows:

- Week 1: Icy road: Send unarmored supply trucks on India Route 1 because they are more likely to get through icy road conditions than armored supply trucks.
- Week 2: Vulnerable bridge: Send Town Oscar convoy on Route 2 with higher threat level because Route 1 has a bridge which would likely be attacked.
- Week 3: Population shift: Change the quantity of supplies sent to each town in response to temporary population shifts caused by a regional election.
- Week 4: Civilian guard preference: Hire civilian guards for Town Oscar instead of professional guards because they will be better received by the population of this town.

Adaptive Planning Results

Adaptive Planning Embedded Problems. The adaptive planning manipulation embedded one specific problem situation in each of the four weeks that planning groups need to recognize and respond to for successful Humanitarian Supply Unit (HSU) delivery. The embedded problems require that group members gather, exchange, and integrate information to form their weekly plans. It was anticipated that groups in the co-located condition might be better able to adapt their plans in response to changes in the environment, as represented by the embedded problems. An estimate of group adaptive planning was calculated as the total number of embedded problems successfully resolved. Values on the Adaptive Planning estimate ranged from zero (no problem situations successfully resolved) to three (three of the four problem situations resolved), (m = 1.71, sd = .99). An independent-samples *t* test comparing the Adaptive Planning scores for groups performing in the co-located and distributed planning conditions did not find a significant difference between the means of the two groups ($t(12) = 1.08$, $p > .05$). The mean for the distributed condition was not significantly lower (m = 1.43, sd = .98) than the mean of the co-located condition (m = 2.00, sd = 1.00).

A Pearson correlation was calculated to estimate the relationship between the Percentage of Required Supplies Delivered – Square Root (PRSD SQRT) measure and Adaptive Planning scores for both the co-located and distributed group conditions. Only a weak negative correlation was found for the co-located condition ($r(5) = -.05$, $p > .10$). In contrast, a moderate significant positive correlation was found for the distributed condition ($r(5) = .70$, $p < .05$). These findings provide some evidence that for the distributed planning condition, differences exist in the ability of groups to adapt their plans in response to changes in the environment, which contributed to observed differences in the delivery of humanitarian relief supplies.

Discussion

The Army Training Plan has singled out adaptability as a critical skill to be trained. The REPSS performance measurement approach included the use of embedded problems to detect each group's ability to adapt their planning solutions in response to changing demands. The embedded problem measurement approach did identify a significant relationship between adaptive planning and success in delivering relief supplies for the distributed planning condition.