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Radio Communications and Situation Awareness of Infantry Squads during Urban Operations

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14. ABSTRACT *(Maximum 200 words)*:

This research evaluated the frequency and content of squad radio communications, and reevaluated situation awareness (SA) data collected by others. Both sets of data were collected using 14 Ranger squads executing urban operations driven by scripted vignettes. The radio communications data highlighted factors that influence and determine the consequences of squad radio communications. These data were differentially sensitive to communications about friendly and threat conditions as well as mission and visibility conditions. Important moderating factors for these results were differences found for downward- and upward-directed communications and conflicting requirements for processing information under conditions of information overload. The reanalysis of the SA data yielded separate measures of SA for squad leaders and their subordinates, and for top-down and bottom-up sources of knowledge about battlefield conditions. The fine-grain reanalysis of SA data showed effects not previously reported and clarified some that were. The data emphasize the need to consider echelon differences in estimating the

15. SUBJECT TERMS

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FOREWORD

The Infantry Forces Research Unit of the U. S. Army Research Institute for the Behavioral and Social Sciences conducts research that contributes to a better understanding of soldier-based issues under its *Training Modernization for Infantry Forces* research program. In support of this objective, it participated in several field experiments under the auspices of the Military Operations in Urban Terrain (MOUT) Advanced Concepts Technology Demonstration (ACTD) program. One recent experiment was concerned with evaluating the impact of radio communications at the squad level of light infantry operations. In line with current thinking about the promise of new technologies, the use of a squad radio should permit members of a squad to receive and share critical information about the combat environment. Likewise, it is assumed that increased levels of information about the combat environment would improve the infantryman's situation awareness and hence his operational behaviors and combat performance. The recent field experiment investigated the validity of these assumptions.

The present report describes the results of that experiment in terms of the efficacy of the data collection method used for obtaining real-time information about the frequency and content of squad radio transmissions, as well as several alternate measures of squad-level situation awareness. The results showed the importance of differentiating downward- and upward-directed communications on the squad radio and for considering echelon differences in estimating the criticality of battlefield information.

Results from this research were presented to key individuals from the MOUT ACTD program and the Dismounted Battlespace Battle Lab. They will be used at Fort Benning to aid in the design of follow-on experiments. The Infantry Forces Research Unit is currently extending the scope and depth of these findings in other types of light infantry missions and developing communication-based measures of situation awareness.

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Acting Technical Director

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- the Fort Benning Field Unit of the Human Research and Engineering Directorate, Army Research Laboratory,
- the Dismounted Battlespace Battle Lab, and
- the 3rd Battalion, 75th Ranger Regiment.
-

The dedicated, cooperative, and skilled efforts of these many individuals made it possible for the field experiment described in this report to be accomplished with the thoroughness required for a behavioral science project.

RADIO COMMUNICATIONS AND SITUATION AWARENESS OF INFANTRY SQUADS DURING URBAN OPERATIONS

EXECUTIVE SUMMARY

Research Requirements:

Several recent technology demonstrations examined the proposition that intrasquad radio communications would enhance the situation awareness of light infantrymen. While the results of those demonstrations were not consistent in their support of the proposition, they were clear in recognizing that additional research was needed to develop and evaluate methods to accurately assess important attributes of radio communications and to further refine measures of situation awareness in small light combat units. This report presents the results of research that evaluated the frequency and content of squad radio communications and reevaluated situation awareness data collected by others.

Procedure:

The experiment was conducted using 14 U.S. Army Ranger squads at the McKenna Site for military operations on urban terrain, Fort Benning, Georgia. Phase 1 of the experiment determined how five different squad radio procedures related to situation awareness. Phase 2 sought to determine, for both day and night visibility conditions, if measures of situation awareness would be affected by whether the squad was equipped with a squad radio. In both phases, squads executed missions driven by short duration scripted vignettes. When a squad radio was available, the squad leader used it to communicate with his squad members. The squad leader also used a second (platoon) radio to communicate with his platoon leader. He used the squad radio to retransmit to his squad members information about friendly and threat conditions provided to him by the platoon leader. Radio transmissions were categorized and tabulated by whether they provided or requested messages concerned with acknowledgement, direction, information about friendly and threat conditions, and opinion. Using data collected by others through tests of the infantrymen's knowledge of mission-critical events, separate measures of situational awareness were derived for the squad leader and his subordinates, and for top-down and bottom-up sources of knowledge about battlefield conditions.

Findings:

The radio communications data highlighted factors that influence and determine the consequences of squad radio communications. These data were differentially sensitive to communications about friendly and threat conditions as well as mission and visibility conditions. Important moderating factors for these results were differences found for downward- and upward-directed communications and conflicting requirements for processing information under conditions of information overload. The reanalysis of the situation awareness data yielded separate measures for squad leaders and their subordinates, and for top-down and bottom-up sources of knowledge about battlefield conditions. The fine-grain reanalysis of the situation awareness data showed effects not previously reported and clarified some that were. These data emphasize the need to consider echelon differences in estimating the criticality of battlefield information, as well as the impact on situation awareness of visibility and information overload

conditions. Taken together, the results underscore the fact that reliable explanations of the relationship between squad radio usage and squad situation awareness rely on detailed analyses of both factors.

Utilization of Findings:

The results of this research will support the design of future research to evaluate the contribution of radio communications on the combat performance of small lower echelon units and the impact on situation awareness of using squad radios to provide critical battlefield information to light infantrymen during the planning and execution of combat operations.

RADIO COMMUNICATIONS AND SITUATION AWARENESS OF INFANTRY SQUADS DURING URBAN OPERATIONS

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RADIO COMMUNICATIONS AND SITUATION AWARENESS OF INFANTRY SQUADS DURING URBAN OPERATIONS

INTRODUCTION

A light infantry squad currently has only one radio. The squad leader (SL) only uses it for communications with his leader, the platoon leader (PL)[1]. Communications within the squad occur using normal vocalizations or non-verbal methods (e.g., arm and hand signals). However, the SL and other squad members (SMs) may need to communicate with one another when normal vocalizations are not appropriate (e.g., they could be heard by the threat force) or when non-verbal communications are insufficient or not possible (e.g., the content of the communication is complex or the squad members cannot see one another). These considerations alone created interest in equipping all infantrymen with a radio. Some proponents of squad radios argue further that their use would enhance the situation awareness (SA) of infantrymen in the squad and hence their combat effectiveness.

This report presents the results of an analysis of data the authors collected on the frequency and content of squad radio communications during their participation in a recent field experiment. This field experiment was designed and executed by the Fort Benning, Georgia, field element of the Human Research and Engineering Directorate (HRED) of the U. S. Army Research Laboratory (see Redding & Blackwell, 2001). This report also presents the results of a reanalysis of SA data collected by HRED during that field experiment. The purpose of this report is to enhance the information currently available about squad radio communications and SA in the light infantry.

Background

A recent series of demonstrations examined the impact on light infantry operations of commercial and government off-the-shelf technologies. These demonstrations were conducted under the auspices of the Military Operations in Urban Terrain (MOUT) Advanced Concepts Technology Demonstration (ACTD) program. One of the technologies examined was a radio that could facilitate intra-squad communications. The military utility of this particular radio technology, i.e., the squad radio, was evaluated in a series of three Army and two joint Army-Marine Corps demonstrations (see Dismounted Battlespace Battle Lab [DBBL], 1998, 1999a, 1999b, and DBBL & Marine Corps Warfighting Lab [MCWL], 1999, respectively).

The Frequency and Content of Squad Radio Communications

The junior author of this report participated in these technology demonstrations as a representative of the U.S. Army Research Institute (ARI). One of the issues he addressed was

[1] Since service in close combat units, to include infantry platoon and squads, is restricted to males only, masculine gender pronouns are used to refer to infantrymen in general and to the participants of this research in particular.

the need to develop a method for obtaining information about the frequency and content of squad radio transmissions. The lack of recording equipment necessitated that these transmissions be categorized in real time, without relying on tape recordings or written transcripts. Although there was one rater with an extensive military background and another with an extensive research background, the initial attempts at categorizing the content of real-time radio transmissions during the MOUT demonstrations were largely unsuccessful. A categorization scheme reported in Bowers, Jentsch, Salas, and Braun (1998) was used, but the agreement between raters was poor. With no workable taxonomy available, one was developed by the junior author. Similar in some respects to the Interaction Process Analysis system of Bales (1950), the taxonomy of radio transmissions developed and used for the last of the MOUT ACTD experiments is shown in Table 1.

Table 1. Taxonomy of Radio Transmissions Used for the MOUT ACTD (as reported in DDLB & MCWL, 1999)

Communication Category	**Examples**
Provide Acknowledgment	Roger, moving out. Three Six, this is Three One, go ahead.
Provide Direction	Cuff and search them. Suppress the second floor of the blue building.
Provide Information (Friend)	Alpha team is at the bottom of the stairwell. We've got one KIA and two wounded, over.
Provide Information (Threat)	There's two with rifles in the front room. Be advised, I can hear movement upstairs.
Provide Opinion	I don't think we can, without more support. We'll whip their ass if they come through here.
Request Acknowledgment	How copy? Three One, this is Three Six, over.
Request Direction	What do you want us to do with the prisoners? Where do you want the smoke?
Request Information (Friend)	What's your status, Three Two Bravo? Tell me when you're in position.
Request Information (Threat)	How many and where? OP, see anything yet?
Request Opinion	What's the best way to enter that building? Well, when do you think you'll be ready?
Unrelated to Mission	Bite me. Can we wait till tomorrow to police the range?
Administrative/Other	Radio checks. Acknowledge start of a freeze period.
Inaudible	Voices heard, but they could not be understood.

This categorization scheme yielded several trends in the analysis of MOUT radio transmissions (DBBL & MCWL, 1999). First, radio transmissions in the categories of provide and request acknowledgment accounted for an average of 45 percent of total transmissions. This finding was consistent with that of Phelps and Kupets (1984), who investigated the radio

transmissions of leaders at squad and higher echelons during National Training Center exercises at Fort Irwin, CA. Second, some mission-related effects were found, most notably that the frequency of communications in the categories of provide and request information about threat was substantially higher during defensive missions than during offensive missions. Third, transmissions in the unrelated to mission category were found to be directly related to what the unit was doing. Transmissions in this category almost never occurred when personnel were in contact with a hostile force. Rather, they tended to occur during long periods of movement to contact or idleness.

Squad Radio Communications and SA

The issue of whether squad radio communications would enhance the SA of infantrymen was investigated by HRED during the last set of MOUT ACTD exercises and in a subsequent field experiment. These two investigations were described in two successive reports by Redden and Blackwell (2000, 2001). Several procedural issues, some results, and key conclusions associated with these two investigations are described in the following two sets of labeled paragraphs.

Measures of SA during free-play scenarios. Redden and Blackwell (2000) described an evaluation of the SA of leaders drawn from both Army and Marine platoons during the execution of free-play scenarios in the two joint MOUT ACTD exercises. During both joint exercises, the units conducted day and night trials, both with and without squad radios. Measures of SA were based on the questionnaire assessment of situation knowledge and freeze-frame techniques used by Endsley (1995). The freeze frames and SA assessments occurred before the attack phase, after the consolidation phase, and after a defensive counter-attack phase of each trial in both joint exercises. Three results of this evaluation were reported. First, there was a significant increase in SA measures between the two joint exercises but only for the trials in which squad radios were used. Second, during the second joint exercise, the overall results showed that SA was higher on trials in which the squad radios were used than on baseline trials without a squad radio. However, this difference was significant for night trials only; there was no effect for squad radio usage for daytime trials. Third, the difference in SA on trials with and without squad radios was significant only during the consolidation phase of the trial; there was no difference in SA scores before the attack phase or after the defensive phase of the trials.

Redden and Blackwell (2000) noted that the increase in SA between the two joint exercises for only the squad radio condition showed there was a learning effect for using the squad radio. They also concluded that the favorable contribution of the squad radio on SA was greatest during night trials when visibility was limited and during the consolidation phase of the operation when the participants were more widely dispersed than they were during the offensive and defensive phases. These investigators also cautioned that the results reported for these experimental trials might have been caused by the many uncontrolled variables that occurred during the free-play field exercises, and that the long duration of these free-play trials (exceeding one hour) limited the number of trials that could be conducted.

Measures of SA during scripted scenarios. Redden and Blackwell (2001) described a method for structuring squad-level MOUT field exercises that would retain the strengths of the

free-play method they used in the joint MOUT ATCD exercises while minimizing its weaknesses. In short, they developed and used short-duration field-based vignettes that permitted the squad under investigation to operate as it would in free-play exercises, while critical events in the combat environment and the activities of threat force and civilians on the battlefield, as well as radio communications of the PL, were controlled by being carefully scripted.[2] This method of structuring field exercises ensured that the maximum number of most critical, difficult, and time-consuming tasks were incorporated into and were the focus of the squad during experimental trials. Measures of SA were derived from tests that assessed the infantrymen's knowledge of critical events or activities that occurred during each trial. The SA Knowledge Tests were administered at the conclusion of each trial.

The experiment reported by Redden and Blackwell (2001) was conducted in two phases. Phase 1 was concerned principally with addressing one important variable that was uncontrolled in previous exercises. Specifically, observations made during those exercises suggested that additional guidance and practice was needed before infantrymen could learn to use the squad radios effectively. In the first MOUT ACTD trial involving radio-equipped soldiers, an Army platoon began a defensive mission with members of each of its squads communicating on separate channels of the squad radio (DBBL, 1998). Observations made during this trial showed that there was a high volume of radio traffic and that many of the transmissions were chaotic in nature. Consequently, before the next trial in this exercise, the PL disconnected the microphones of most SMs and announced that henceforth only SLs and their two fire team leaders (TLs) could transmit radio messages. Subsequent MOUT ACTD exercises with squad radios also illustrated the need to put at least some restrictions on the communication of SMs, though such restrictions need not be as drastic as disconnecting microphones (DBBL, 1999a, 1999b; DBBL & MCWL, 1999). Each PL in the subsequent MOUT ACTD exercises was free to use whatever squad radio procedures he thought most relevant. Although some procedures appeared to be more effective than others were, they were not subjected to experimental manipulation and the number of trials observed with any one set of procedures was low.

In Phase 1 of the experiment, each of five Army Ranger squads was trained to use each of five different procedures governing the use of the squad radio by SMs. These squad radio procedures were defined as tactics, techniques, and procedures (TTPs) by Redden and Blackwell, 2001. The TTPs were evaluated under daylight conditions only to identify the one TTP that was most effective for establishing SA in the urban operations being investigated and for subsequent use in Phase 2. Redden and Blackwell reported that the average measure of SA was higher for one TTP condition than for each of the other four. This TTP condition (TTP 1 in their study) was the one in which only the SL could transmit messages using the squad radio. Redden and Blackwell (2001) attributed this finding to two factors. First, the information transmitted by the SL on TTP 1 trials was likely to be more critical for the conduct of the mission than that transmitted by other members of the squad in the other TTP conditions. Second, the other TTP conditions permitted more information to be transmitted by more participants, but this fact would increase the potential for cognitive overload. The results obtained in Phase 1 using SA Knowledge Test results contrasted with those obtained when participants were ask to rate their

[2] Since the present report is based on data collected during the experiment reported by Redden and Blackwell (2001), the method they used to insert control over otherwise free-play exercises as well as other methods they employed are more fully summarized in later sections of this report.

SA using a 7-point scale. The mean of their rated personal SA was lower under TTP 1 conditions than it was for all but one of the other TTP conditions. The mean rated SA was highest for the TTP condition (TTP 5) that permitted all SMs to transmit messages to the SL as well as to all other SMs.

Phase 2 of the experiment evaluated directly the contribution of squad radio usage on SA. Nine Ranger squads were trained to operate under the TTP 1 condition for squad radio usage. Each squad participated in 12 experimental trials. The first six trials occurred during daylight and the second six trials occurred during night viewing conditions. A completely different set of three vignettes was used for the two viewing conditions. Each vignette was used twice (once with and once without the squad radio), but with different scripts used for the two squad radio conditions. Redden and Blackwell reported average SA in Phase 2 was significantly degraded during night operations without the squad radio. They reported no difference in average SA between day and night conditions when the squad radio was available or as a function of squad radio during daylight operations.

In both of their reports, Redden and Blackwell (2000, 2001) concluded that squad radios may contribute to SA only during periods of limited visibility and when troops are more dispersed. Under these conditions, participants were unable to see one another and hence were unable to communicate using arm and hand signals. In both reports, they also emphasized that care needed to be taken to determine critical information requirements since these requirements will differ as a function of echelon. In their first reported they noted, "ground troops are very focused on knowledge that will keep them alive and should not be expected to know information that is outside their area of interest and influence" (p. 135). The ratings by infantryman of critical information requirements in Redden and Blackwell (2001) supported this observation. While the SL and TLs indicated that information about command and control issues were critical, other members of the squad "were only concerned with the location of the [threat force] on the squad objective" (p. 20).

Finally, Redden and Blackwell (2001) described some unique features of Army Rangers. Rangers were selected to participate in the second study because they already had some experience using squad radios and would not need long periods of training to acquire skills needed for their proper use. Redden and Blackwell also presented rating data obtained from exercise controllers that highlighted the Rangers high levels of discipline and performance. Finally, these authors noted, "the Rangers were highly trained in silent [forms of] communication (and thus not as dependent on verbal communications)" (p. 26). The implication is that less well trained and disciplined infantrymen may use the squad radios quite differently than did the Rangers.

Objectives

As stated previously, the purpose of this report is to present research results that enhance the information currently available about squad radio communications and SA in the light infantry. One objective of the present research was to collect data that would evaluate the efficacy of the method proposed for measuring the frequency and content of radio communications. Clearly, not all radio transmissions are equal in terms of their potential contribution to squad SA and

combat performance. One set of research issues was concerned with potential differences in squad radio usage by the SL and SMs. Another set of research issues was concerned with the effects on squad radio usage of transmissions between the SL and PL on a second radio (i.e., the platoon radio).

A second research objective was to reanalyze the SA data collected by Redden and Blackwell (2001) and to evaluate and extend some of the conclusions they proposed concerning the determinants SA. They were unable to provide adequate support for some of these conclusions because (a) SA Knowledge Test results were averaged over all participants and, in the second study, over offensive and defensive mission vignettes and (b) the SA measures in both their studies were averaged over different sources of critical information. The present research addressed these issues directly. It furthermore used the squad as the unit of analysis rather than the individual participant.

In the absence of previous controlled experiments addressing the objectives and issues outlined above, and without available theory to guide the development of precise predictions, the research described in this report was more exploratory than formal. It was expected that the methods used for assessing the frequency and content of squad radio communications would yield results that parallel those described in the last set of MOUT ACTD exercises (DBBL & MCWL, 1999). It also was reasonable to expect that the reanalysis of previously collected SA measures would yield results in concert with those reported and discussed by Redden and Blackwell (2000, 2001). Overall, the expectation was that the results of this research would permit the development of formal hypotheses for subsequent testing in future research.

METHOD

Since this report is based upon data collected during the experiment reported by Redden and Blackwell (2001), most details of the method are presented in their report. The method was outlined in the introduction to this report. This section focuses on several aspects of their experiment not covered in their report. In addition, this section describes methods used by the authors to assess the frequency and content of radio communications and to reanalyze the SA data collected initially by Redden and Blackwell.

Simulated Combat Exercises

The MOUT exercises used during experimental trials were partially constrained by means of written sketches or vignettes. These vignettes described relatively short duration combat incidents or situations. Two offensive mission vignettes and one defensive mission vignette were written for use in Phase 1 of the experiment and for the Phase 2 trials conducted during daylight conditions. Three other vignettes (all for offensive missions) were written for use in the Phase 2 trials conducted during night viewing conditions. During an offensive vignette, the squad attacked and cleared a building or a section of a building. During a defensive vignette, the squad occupied the second floor of a building and prepared for a counterattack. Since each squad was evaluated over multiple trials, multiple scripts were written for each of the six vignettes. Each of the Phase 1 vignettes was prepared with five different scripts. Two of the

scripts for each of the Phase 1 vignettes were used also for the Phase 2 daylight trials. Two scripted versions were prepared for each of the Phase 2 night trial vignettes. (An example of a scripted vignette as described by Redden & Blackwell (2001) is given in Appendix Table A-1.) On each experimental trial, eight evaluator/controllers monitored and controlled the activities of the various players to ensure they operated within the parameters established for the particular scripted vignette being used on that trial.[3]

Use of the Squad Radio

During both phases of the experiment, the scripted communications of the PL were transmitted to the SL only using a platoon radio (i.e., the AN/PRC-126 FM radio). When the squad was equipped with a squad radio (i.e., the ICOM intra-squad radio), the SL was specifically instructed and encouraged to use the squad radio as his primary means of communicating with his SMs. While not reported by Redden and Blackwell (2001), the SL was told that when he had a squad radio, he was to use it to retransmit to his SMs the scripted information provided to him by the PL on the platoon radio.

While the SMs equipped with a squad radio could always receive (i.e., hear) messages being transmitted on the squad radio, they were not to initiate a radio transmission unless authorized to do so by the experimental procedures. Five different procedures were investigated in Phase 1 of this experiment for controlling which SMs had explicit permission to transmit messages on the squad radio, as well as to whom and under what conditions they could do so. The five squad radio procedures (i.e., tactics, techniques, and procedures or TTPs) were summarized on a small laminated card given to each participant. This card showed on one side a summary of how the TTPs differed from one another and, on the other side, how they were similar to one another. Major features of both sides of this card are presented in Table 2.

Participants

Army Ranger units that had experience using squad radios were selected for the experiment. The Rangers used were drawn from elements in the 3rd Battalion, 75th Ranger Regiment at Fort Benning, Georgia. A Ranger squad consisted of the SL and two rifle teams. Each rifle team consisted of a TL and three riflemen serving as team members (TMs). While each Ranger squad normally contained nine participants, the actual numbers of participants per squad varied slightly over experimental trials. Since the unit of analysis was the squad rather than individual infantrymen, this variation in squad size did not affect the results. Five Ranger squads participated in Phase 1 and nine Ranger squads in Phase 2. Phase 2 squads were drawn from three platoons different from those that participated in Phase 1.

[3] Except for the initial trial of two squads in Phase 1, all squads used the radios in accordance with the TTP condition prescribe for a given trial. The exceptions were caused by two Ranger squads that successfully completed their assigned offensive mission without ever using the squad radio. Consequently, the correct procedures for using the squad radio were reiterated to all Phase 1 participants. The designated TTP was correctly followed in all subsequent trials. The PL as well as the contractors that played the roles of threat elements and civilians on the battlefield generally performed as required by scripts.

Table 2. Five Squad Radio Communication TTPs Used during Phase 1

Squad Radio Communication Procedures (TTPs)[a]

Differences

TTP 1	**Don't Talk**	• Team Leaders (TLs) and team members (TMs) cannot transmit.
TTP 2	**TL to SL Only**	• TLs can transmit at any time, but only to the SL. The TMs cannot transmit.
TTP 3	**When SL Asks**	• TLs and TMs cannot transmit, unless the SL asks them to transmit to him. TLs and TMs cannot transmit again until the SL asks them to transmit to him again.
TTP 4	**Up and Down**	• TLs can transmit to their TMs and to the SL at any time. The TMs can transmit to their TL or to the SL at any time.
TTP 5	**Free Talk**	• TLs and TMs can transmit to anyone in the squad at any time (including TL to TL and TMs to TMs in other teams).

Similarities

- The SL can always transmit messages to anyone in his squad at any time.
- Everyone can always listen to squad radio transmissions.
- Everyone can use hand and arm signals at any time.
- If a TTP allows you to transmit, use the squad radio as your primary means of verbal communication.
- If a TTP forbids you to transmit and you need to say something out loud, communicate the way you normally would without a squad radio.

[a] While not communicated to the participants, the numbers used to identify the TTPs reflect the ordinal relationship among the TTPs in terms of the number of possible SM transmissions permitted: none, 2, 8, 20, 64 for TTP 1 though TTP 5, respectively.

Phase 1 Procedures

The first half of the first day of Phase 1 was devoted to orienting all participating soldiers to the experiment and providing them training for using the five squad radio TTPs. The junior author of this report conducted the TTP training. Upon completion of the training, he administered a short survey to 41 Rangers who had participated in the training, asking them to compare these TTPs to how they had used a squad radio during previous exercises. Over 80 percent of those expressing an opinion (30 of 37 Rangers) indicated that TTP 5 was most similar to the procedures used by their unit and the remainder chose TTP 4.[4] (This survey and the results it produced are given in Appendix Table A-2). The Rangers were told to keep the laminated cards that described squad radio procedures and to use them, as necessary, prior to the start of each trial, as an aid for remembering the TTP called for during that trial.

[4] Redden and Blackwell (2001) indicated that TTP 1, amended so that any SM could transmit a critically important message, was the most common TTP used by the Rangers. However, since Rangers are trained to operate with minimal need for vocal communications, they are normally expected to maintain radio silence unless there is a critical message to share with others. Consequently, as amended in the Redden and Blackwell definition, TTP 1 is essentially equivalent to TTP 5 exercised with disciplined radio silence. This latter conclusion was corroborated by informal discussions with current Rangers and a member of the DBBL staff (G. Beckwith, personal communication, June 9, 2002).

Each squad experienced each of the five TTP conditions combined with each of the three Phase 1 vignettes for 15 trials. Each squad participated in three trials with one TTP condition and all three vignettes, before it participated in trials with another TTP condition. The 75 Phase 1 trials were conducted during daylight hours and were completed in six normal working days. (The order of experimental conditions for each squad in Phase 1 is given in Appendix Table A-3.)

Phase 2 Procedures

The three squads from each platoon completed their respective participation over five successive weekdays. At the beginning of their first day of participation, the Rangers in each platoon received a one-hour orientation to the experiment and training for using the squad radio TTP that was associated with the highest average individual SA in Phase 1 (TTP 1 in Table 2).

Each squad of each platoon completed 12 trials during their assigned week. On six trials, there was no squad radio available to the squads (baseline condition), and on another six trials, the squad radio was available and used (squad radio condition). Two day trials were conducted on each of Monday, Tuesday, and Wednesday, and two night trials on each of Wednesday, Thursday, and Friday. (The order of experimental conditions for each squad in each platoon is given in Appendix Table A-4.)

Situation Awareness Knowledge Test

The SA Knowledge Test administered at the conclusion of each trial contained ten to twelve questions to ensure coverage of all battlefield operation systems (U.S. Army, 2001) and the three levels of SA (i.e., perception, comprehension, and projection) proposed by Endsley (1995). (An example of one of these tests is presented in Appendix Table A-5.) However, the participant's responses to all items were not included in the HRED measurement of SA. Instead, only responses to a limited set of critical questions were used to estimate an infantryman's SA for a trial. Participants rated the criticality of each question after responding to all items in the SA Knowledge Test. Critical questions in each phase were those with mean ratings across all participants that indicated the question referred to knowledge that was essential, necessary, or extremely necessary for successful accomplishment of the mission. Three to five questions were judged critical for the various scripted vignettes. The individual infantryman's SA score for each scripted vignette was the percentage of these critical questions he answered correctly. (An example of the critical questions established for each of the five scripts used for one vignette in Phase 1 of the experiment is presented in Appendix Table A-6.)

Procedures for Determining Situation Awareness Measures for this Research

Responses to only critical test items were transferred to ARI for use in this research. Two different versions of these data were provided. In one version, the soldier-level SA Knowledge Test data, the percentage correct performance score was given for each individual soldier for each of the SA tests he took. The second version of the SA data, the squad-level SA Knowledge

Test data, gave the number of soldiers in each squad that correctly and incorrectly responded to each critical question in each SA test administered to the squad.

Three estimates of SA for each trial were derived from the soldier-level SA Knowledge Test data. (a) The percentage correct score of only the SL was used to estimate the SA of the SL on every trial (SLSA). (b) The mean percentage correct score over all the SMs in a squad who participated in a trial and who took the test for that trial was used to estimate the SA for the SMs only on each trial (SMSA). (c) The mean percentage correct score over the SMs and SL in a squad who collectively participated in a trial was used to estimate the SA of the squad as a whole (SqdSA) for each trial.

Two additional measures of SA were derived from the squad-level data. These measures were based upon the results of a crosswalk performed for each scripted vignette between critical questions in the SA Knowledge Test and the scripted messages provided by the PL to the SL. In one case, if correctly answering a question depended on information available only from the scripted PL communications, it was defined as a top-down test item. If not a top-down item, correctly answering the question had to depend upon observations made directly by the SL or SMs and it was defined as a bottom-up test item. The mean percentage of soldiers in the squad (including the SL) correctly responding to the top-down test items for each trial was used to estimate top-down SA. Similarly, the mean percentage of soldiers in the squad (including the SL) that correctly answered the bottom-up test items for the trial was an estimate of bottom-up SA.

Method for Assessing the Type and Frequency of Communications

Using the taxonomy shown in Table 1, it was possible for one data collector who had extensive military experience to monitor and record in real time the frequencies of the different categories of transmissions that occurred on both radios during the experimental trials. The method used to tabulate radio communications was facilitated by use of a three-column data collection form.[5] (A copy of this form is presented in Appendix Table A-7.) Two copies of this form were used for each trial, one to assess communications on the platoon radio and the other to assess communications on the squad radio. On both forms, the transmission categories shown in Table 1 were listed in the left-most column of the form and the second column was used to tally the frequency with which the SL transmitted different categories of communication over one or the other radio. Depending on the radio over which the message was being transmitted, the third column of the form was used to tally the frequency with which either the PL or SMs transmitted different categories of communication. The script appropriate for each trial controlled the transmissions of the PL but, while the TTP condition determined which SMs could communicate, there was no constraint on what the SMs transmitted when they did.

The process of tallying the type and frequency of radio transmissions was facilitated by constraints existing in the communications environment itself and several imposed by the data

[5] The reliability of this method and the data collection form for real-time tabulation of radio transmissions was established in another investigation of infantry squads during urban operations. Two trained data collectors each independently monitored 207 separate squad radio transmissions. They agreed in their tabulation of message category on 202 (97.6 %) of these transmissions.

collection process. Examples of the latter type of constraints include the fact that the initiator of a squad radio transmission was designated as either the SL or a SM. It would have been difficult and no attempt was made to discriminate and record which specific SM might have initiated a transmission. Likewise, there was no requirement for the data collector to discriminate and record for whom a squad radio transmission was intended. Finally, there was no requirement to identify and record detailed aspects of the information contained in a communication about the combat environment. Following the logic used to script the PL inputs to the SL, a message was designated as being about friendly conditions if it contained information about the status, activities, or observations of friendly elements, regardless of whatever else might be included in the communication. All other messages, i.e., those containing information about the status and activities of only threat elements or civilians on the battlefield, were scored as being about threat conditions.

Assessing Retransmissions of Scripted Message Elements

The information each SL provided to his SMs was assessed to determine the extent to which the SL retransmitted the scripted messages provided to him by the PL. To facilitate this assessment, each scripted PL message was partitioned into its component elements. The number of message elements in the 15 scripted vignettes used in Phase 1 varied from as few as 10 to as many as 34. The number of message elements in the 12 scripted vignettes used in Phase 2 varied from 16 to 39. A list was prepared for each scripted vignette that identified message elements in the order in which they were to be transmitted to the SL. The data collector used the appropriate list to tally the number of scripted PL message elements retransmitted by the SL during each experimental trial. (A copy of a check sheet for message elements is presented in Appendix Table A-8.)

During tabulation of retransmitted message elements, a distinction was made between two types of elements. Some were designated as essential elements because information contained in the message element or that could be derived from it was required to correctly answer items in the SA Knowledge Test that were previously defined as top-down questions. All other message elements were designated as nonessential elements. The number of essential elements per scripted vignette varied from 2 to 7 in Phase 1 and from 0 to 8 in Phase 2. It was noted previously that correctly answering bottom-up questions was based on observations made directly by participants rather than on scripted PL messages that were retransmitted over the squad radio.

Experimental Design

Due to the particular experimental method used, it was not useful or appropriate to analyze all the data concurrently for all levels of each independent variable. Table 3 illustrates actual and potential constraints on radio communications for combinations of three independent variables that were potential sources of variance for the communications data collected on every trial in both phases of the experiment: (a) the radio used for communication; (b) the duty position of the communicator; and (c) the action taken by the communicator in his transmission. The frequency of transmissions initiated by the PL was not a dependent measure. Rather, these values were determined directly by the scripted vignette used on the trial. Furthermore, if the SL was

retransmitting to the SMs the information provided by the PL, at least some of the input the SL provided to the SMs was driven by the scripted PL communications. To an undeterminable extent, the inputs provided by the SL to the PL were likely influenced by the PL's scripted requests for inputs from the SL.

Table 3. Illustration of Actual and Potential Constraints on Radio Communications

Action of Communicator	Radio Used by and Duty Position of Communicator			
	Platoon Radio		Squad Radio	
	PL	SL	SL	SM
Provide Input	Entirely Scripted	Reply to PL Otherwise None	Resends PL Info. Otherwise None	None, If Permitted
Request Input	Entirely Scripted	None	None	None, If Permitted

Note. Shading in the cells of the table reflect communications determined or influenced by the scripted PL transmissions.

Except where noted, the statistical method used was the analysis of variance. Since squad-level data served as the dependent variable in all analyses, sample size was the number of squads participating in the experiment, i.e., n = 5 for Phase 1 and 9 for Phase 2. One of the analyses of variance designs used to examine the frequency of radio communications was a purely repeated-measures design that analyzed the data drawn from only the SL duty position. In this design, the radio used by and the actions of the SL were repeated-measures sources of variance. Another experimental design used was a mixed design that analyzed the data drawn from only squad radio transmissions. This latter design used position as a between-subject (actually, a between-squad) source of variance and action as a repeated-measures source of variance. If the particular category of radio communication being analyzed were information about friendly and threat conditions, information type also would be a repeated-measures variable for both designs. Furthermore, other repeated-measures variables would enter the analysis for both designs depending on the specific experimental conditions being examined (e.g., TTP and mission for Phase 1 data, mission for Phase 2 daylight data, and squad communication and visibility for all Phase 2 data).

Since there was no interest in or value to be gained by analyzing the results of this experiment as a function of the two different offensive vignette trials and one defensive vignette trial, the mean value was determined for the two offensive vignettes for all radio transmission and SA measures. The average results for the two offensive vignette trials were used along with corresponding data from the single defensive vignette trial to establish a two-level mission treatment (offensive and defensive). This mission treatment was subsequently factored into all analyses of Phase 1 data and for analyses of Phase 2 data derived from daylight trials.

Finally, it was determined that the duration of experimental trials was affected by only the mission condition.[6] Defensive mission trials were longer than the offensive mission trials

[6] Trial duration in Phase 1 was analyzed as a function of two levels of mission (defensive and offensive) and five levels of TTP in a repeated-measures analysis of variance. Trial duration in Phase 2 daylight trials was similarly analyzed as a function of mission and the baseline and squad radio conditions. Analyses of trial duration for Phase 1

(respectively, 16.2 and 10.7 minutes for Phase 1, and 16.1 and 9.7 minutes for Phase 2 daylight trials). The difference in trial duration as a function of defensive and offensive missions presents a dilemma for explaining the effect of mission type on communication frequency. Both mission type and trial duration can independently affect the frequency of communications during a trial. For example, a higher frequency of communications could occur on the longer duration defensive trials than the shorter duration offensive trials either because of differences in the amounts of communications appropriate for these two types of missions or because of the time available for transmitting messages. Since we used the frequency of radio transmissions to determine the impact of experimental treatments on the radio communications, the confounding effect of trial duration and mission type needs to be kept in mind as the results are interpreted and discussed.[7]

RESULTS – PHASE 1

Frequency of Squad Radio Communications in Phase 1

Table 4 presents the mean number of communications per trial (averaged over levels of TTP and mission) for each major category of message content[8] as a function of the radio used and the duty position and action of the individuals using each radio. While the PL communications data were not used in statistical analyses, they are presented in Table 4 to be compared and contrasted with those presented for the other participants. Communications data for message categories that were transmitted one or more times per trial are presented in bold font in the table. A quick look at the contents of Table 4 shows meaningful variation in the frequency of communications for only acknowledgement and battlefield information. There were rarely any communications about an opinion and, except for the SL using the squad radio, almost no communication concerned with providing or requesting direction.[9]

Frequency of Communications Concerning Acknowledgement

It was expected that the acknowledgement category of communications would account for a large proportion of all communications. The results show that this was clearly the case for communications on the platoon radio. Overall, 63 percent of platoon radio communications

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and Phase 2 showed that only the main effect of mission was significant, $F(1, 4) = 85.2$ and $F(1,8) = 217.4$, respectively, $p < 0.01$ in each case.

[7] There was no obvious transformation of the frequency of communications data that would have avoided this confounding effect without introducing other problems. For example, meaningful transformations of the data to rates of communications would require relatively uniform frequencies of transmissions over the course of a trial. In fact, some data and some anecdotal evidence suggested quite the opposite was true in this experiment. In short, there was evidence that during an offensive trial most of the scripted input from the PL as well as most other radio communications occurred after an objective building was assaulted and secured and during the process of reconsolidation. On the other hand, during defensive trials there was evidence to suggest that most of the scripted and unscripted radio communications occur before the culminating firefight began.

[8] There were essentially no administrative, irrelevant, or inaudible message transmissions recorded during experimental trials.

[9] While an examination of the data for the SL providing direction to the SMs showed that more were made on offensive than defensive trials (5.3 and 3.0, respectively), this effect was not significant.

were concerned with requesting or providing acknowledgements. In contrast, messages concerned with acknowledgement constituted only 17 percent of all communications on the squad radio.

Table 4. Mean Frequency of Communications by Message Category in Phase 1 (Averaged over TTP and mission)

Action	Message Category	Radio by Position			
		Platoon Radio		Squad Radio	
		PL	SL	SL	SM
Provide	Acknowledgment	**7.9**	**15.3**	**1.4**	**2.3**
	Direction	0.4	0.0	**4.2**	0.7
	Information (Friend)	**6.9**	**2.7**	**5.2**	**2.7**
	Information (Threat)	**4.8**	**5.3**	**3.7**	**7.3**
	Opinion	0.1	0.0	0.0	0.0
	Overall Provide	**20.0**	**23.4**	**14.5**	**13.0**
Request	Acknowledgment	**12.2**	**6.2**	**1.7**	0.5
	Direction	0.1	0.1	0.0	0.2
	Information (Friend)	**1.5**	**1.4**	**1.8**	0.7
	Information (Threat)	0.8	0.7	**3.2**	0.5
	Opinion	0.0	0.0	0. 1	0.0
	Overall Requests	**14.6**	**8.4**	**6.8**	**1.9**

Note. Data for the PL are presented for comparison with other data in the table. Cells containing frequencies of one or more transmissions per trial are presented in bold font.

An analysis of acknowledgement communications by the SL on both his radios showed that they were much more frequent on the platoon radio than on the squad radio and they occurred principally when he was providing acknowledgements to the PL.[10] Overall, the frequency of PL and SL requesting acknowledgements on the platoon radio (12.2 and 6.2, respectively) was roughly equal to the frequency with which each provided to the other information about battlefield conditions (11.7 and 8.0, respectively). The frequency of the PL and SL providing acknowledgements (7.9 and 15.3, respectively) was comparable to the frequency with which each received information sent by the other 8.0 and 11.7, respectively). The mean frequency of acknowledgement communications on the squad radio was relatively low in comparison to the platoon radio. An analysis of the frequency of acknowledgement communications on the squad

[10] For SL acknowledgement communications on both radios, radio and Radio x Action were significant with $p < 0.01$ [respectively, $F(1, 4) = 2{,}096.4$ and 52.2].

radio showed they were affected by only the TTP condition, increasing linearly from 0.4 for TTP 1 to 2.4 for TTP 5.[11]

Frequency of Communications Concerning Battlefield Information

The more interesting set of findings for message categories, especially from the perspective that radio communications might enhance SA, were those that addressed information about the battlefield environment. Figure 1 summarizes the frequency of this category of communications, averaged over the two types each of information and mission. The two graphs at the top of the figure show mean frequencies of communications about battlefield provided and requested by the SL and PL using the platoon radio as a function of TTP. The two graphs at the bottom of the figure show comparable data for the SL and SM using the squad radio. These data are averaged over the friendly and threat types of information and over defensive and offensive mission conditions.

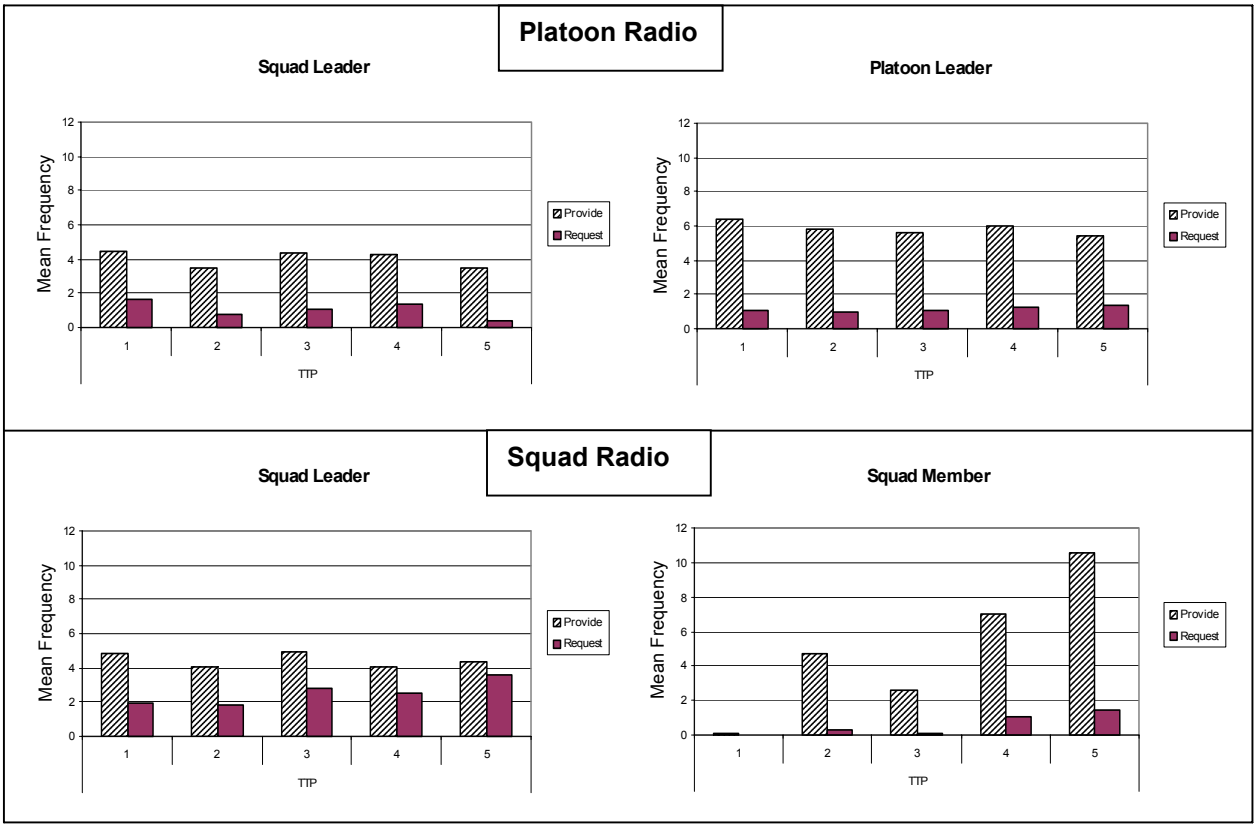

Figure 1. The mean frequency of communications about battlefield conditions in Phase 1 is shown as a function of radio, duty position, action, and TTP (averaged over type of information and type of mission). Communication frequency of the PL is included in the figure to be compared with the data presented for the other participants.

[11] A main effect of TTP was the only significant finding for the frequency of SL and SM acknowledgement communications on the squad radio [$F(4, 32) = 6.7$, $p < 0.01$)].

The results summarized in the figure show that without exception, any effect of TTP on the frequency of transmitting information about battlefield conditions occurred only on the squad radio for the SMs as they communicated with the SL and other SMs. An analysis of communications about battlefield conditions for the squad radio showed significant main effects for TTP and action, as well as the following interaction effects: Position x Action, Position x TTP, Action x TTP, and Position x Action x TTP.[12] An examination of these data showed that while the mean frequency of the SL providing information was about the same as it was for the SMs providing information (4.5 and 5.0, respectively) but it was higher than the mean frequency of SL requesting information (2.5). The mean frequency of the SMs requesting information was very low (0.6). However, these effects of position and action for the squad radio were overwhelmed by the interactions that contain TTP as a component. When the interaction effects included the position treatment, they were caused by there being an increase in communications about battlefield conditions only for the SMs and, then, only when the SMs were providing inputs to the radio.

An analysis of the frequency of communications about battlefield conditions was also conducted for the SL when he used both of his radios. It showed that action was the only significant effect for the frequency of SL communications shown in Figure 1.[13] Averaged over radios, the frequency of SL providing information was higher than his frequency of requesting information (4.2 and 1.8, respectively).

Additional effects involving the type of battlefield information. From Table 4, it can be seen that the frequency of communications about battlefield information was strongly influenced by information type. There was a higher mean frequency of communications about threat conditions than friendly conditions for the SL communicating on both his radios (3.2 and 2.8) as well as for the SL and SMs communicating on the squad radio (3.7 and 2.6, respectively).[14] However, these two main effects for information type each need to be interpreted in terms of three-way interaction effects involving radio, action and information type for the SL using both his radios, and position, action and information type for the SL and SMs both using the squad radio.[15] As can be seen in Table 4, there was a greater frequency of threat information than friendly information when the SL provided input to the PL on the platoon radio, the SL requested input from the SMs on the squad radio, and the SMs provided input to the SL on the squad radio. However, there is a higher frequency of friendly than threat information when the SL provided input to the SMs on the squad radio. There was no difference between communications about friendly and threat conditions when the SL or the SMs requested information from their respective leaders.

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[12] For the squad radio shown in Figure 1, two main effects, TTP and action [$F(4,32) = 15.2$ and $F(1,8) = 61.8$, respectively], were significant along with four interaction effects, Position x Action, Position x TTP, Action x TTP, and Position x Action x TTP [$F(1,8) = 0.4$, and $F(4,32) = 12.2$, 5.3, and 13.1], all with $p < 0.01$.

[13] For the SL using both his radios to communicate about battlefield conditions, the only significant effect was for action, $F(1,4) = 163.8$, $p < 0.01$.

[14] The main effect of information type was significant for the SL using both his radios, $F(1, 4) = 11.8$, $p < 0.05$, and for the SL and SMs both using the squad radio, $F(1, 8) = 48.4$, $p < 0.01$.

[15] The three-way interactions identified were significant for the SL using both his radios, $F(1, 4) = 35.5$, and the SL and SMs both using the squad radio, $F(1, 8) = 47.7$, $p < 0.01$ in both cases.

When viewed from an entirely different perspective, the data in Table 4 for communications about friendly and threat conditions (to include communications by the PL) show that the communicator in the higher relative position for both radios provided to the lower ranking position a higher frequency of communications concerning friendly than threat forces. In contrast, the communicator in the lower ranking position for both radios provided to his counterpart at the higher level a greater frequency of communications concerning threat than friendly forces. Furthermore, when the frequencies for the two types of information are added together, the data presented in Table 4 show that the frequency of messages about battlefield conditions provided to the SL by the PL (11.7) and SMs (10.0) exceeded those the SL provided to them (8.0 and 8.9, respectively).

Additional effects that involve mission. A main effect of mission on the frequency of communicating information about friendly or threat conditions in both sets of analyses was due to more frequent transmissions of information during defensive than offensive trials (respectively, 3.5 and 2.5 for the SL on both his radios, and 3.7 and 2.5 for the SL and SMs combined on the squad radio).[16] The results generally support the expectation that the frequency of communications about threat conditions would be higher during defensive missions than during offensive missions, but they address other relationships as well. Considering only SL communications, there was a higher frequency of communications about threat on defensive mission trials than on offensive mission trials. This was true for both his platoon radio (3.6 and 2.1, respectively) and his squad radio (4.3 and 2.6, respectively).

However, these significant simple main effects were part of a higher-order interaction involving not only mission and information type but also radio and action.[17] In short, the frequency of communications about threat conditions was higher during defensive missions than during offensive mission principally when the SL is providing information to the PL on the platoon radio (6.5 and 4.1, respectively) and when he is requesting information from the SMs on the squad radio (4.6 and 1.8, respectively). Probably because he had to retransmit scripted PL communications to his SMs in this experiment, the frequency of SL communications on the squad radio was also higher for friendly conditions during defensive missions than during offensive missions (6.5 and 3.9, respectively). An alternate view of this higher order interaction is that there was a general tendency for the frequency of SL communications about threat conditions to be equal or higher than communications about friendly conditions except when the SL is providing input to his SMs on defensive missions. In this latter case, the frequency of communications about friendly conditions was higher than communications about threat information.

Interaction effects involving the effect of mission for communications by only the SMs on the squad radio are quite different from those reported for the SL. The TTP condition was also significant for the SMs. Figure 2 illustrates the form of these interactions for the SMs. Since SMs tended not to communicate during TTP 1 trials and not to request information on any trial,

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[16] The main effect of mission was significant for the SL communicating on both his radios, $F(1, 4) = 9.5$, $p < 0.05$ and the SL and SMs both using the squad radio, $F(1, 8) = 37.9$, $p < 0.01$.

[17] For the SL using both his radios, the Mission x Information Type interaction was significant at the 0.05 level, $F(1, 4) = 9.1$, but the 4-way interaction of mission, information type, radio, and action was significant at $p < 0.01$, $F(1, 4) = 24.0$.

the data in Figure 2 are for the frequency of SMs providing information only and only for TTP conditions other than TTP 1. The figure shows that communications by the SMs about threat conditions generally increased as more SMs could freely communicate with more other SMs. Furthermore, for these particular TTP conditions, communications in which the SMs provided information about threat conditions were more frequent during defensive than offensive missions. The fact that the results for TTP 3 was not in line with the other three TTP conditions underscores the fact that SMs were not free to transmit messages in this condition but, rather, had to be asked by the SL before they could communicate. The results just described contrast with those shown in Figure 2 for SM communications about friendly conditions. The frequency of communications in which the SM provided information about friendly conditions were more frequent during offensive than defensive missions, but only if all squad members could communicate with all other squad members. These communications were equally infrequent for both mission types if communications were restricted to the team leaders or to SMs within the communicator's team. Analyses restricted to just the variables shown in Figure 2 support the interpretations just provided for these data.[18]

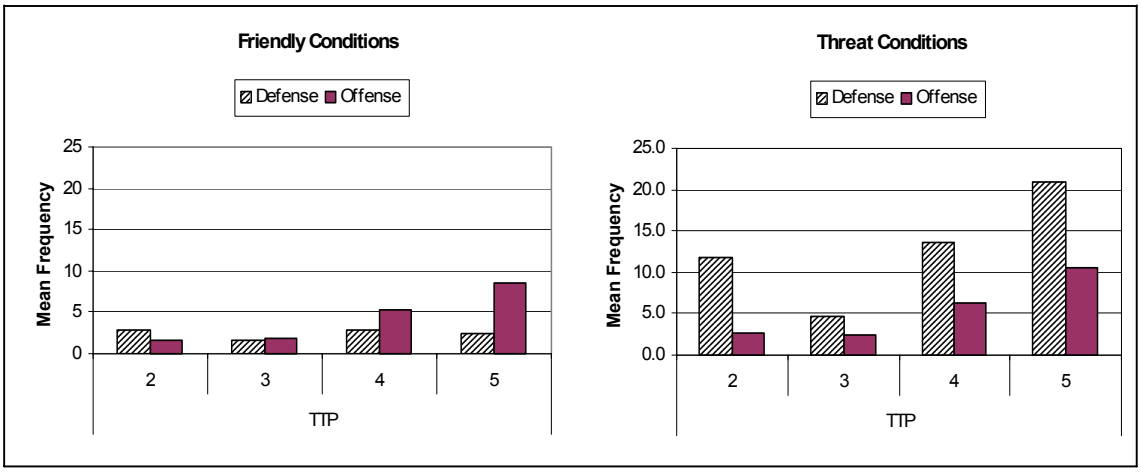

Figure 2. The mean frequency of communications by the SMs that provide information about friendly and threat conditions is shown as a function of mission and TTP.

Retransmission of Scripted Message Elements in Phase 1

An examination of the mean percentage of PL scripted message elements that were retransmitted by the SL showed clearly that the SL did as he was instructed to do. He passed on to his SMs most of the information he received from the PL. Table 5 shows these data averaged over levels of TTP. The data show that the percentage retransmission of message elements was higher for defensive than offensive mission trials, and that the magnitude of this difference was

[18] Analyses performed on only the threat data show in Figure 2 showed that only mission and TTP were significant, $F(1, 4) = 73.8$ and $F(3, 12) = 9.3$, respectively, both at $p < 0.01$. Analysis of the friendly data shown in the figure showed that mission, TTP, and mission x TTP were significant, $F(1,4) = 13.7$, $F(3, 12) = 9.0$ and 8.5, respectively, $p < 0.01$ in each case.

higher for nonessential than for essential message elements.[19] No other effects suggested in the table were significant.

Table 5. Percentage Retransmission of PL Message Elements by the SL in Phase 1 (averaged over TTP)

Message Element	Mission	
	Defense	Offense
Essential	83.9	68.9
Nonessential	87.7	57.8

Measures of Situation Awareness in Phase 1[20]

Analyses of variance tests were applied to each of the three SA scores (SLSA, SMSA, Sqd SA) derived from the individual soldier-level SA Knowledge Test data and to each of the two SA scores (top-down SA and bottom-up SA) derived from the squad-level SA Knowledge Test data.[21] These analyses found evidence for main effects for mission and TTP but not for a mission by TTP interaction. Table 6 summarizes the main effect of mission on the mean percentage correct SA scores for all five SA measures. The data in the table show that SA tended to be higher on offensive than defensive trials for all five SA measures but the analyses showed it was significant for only the bottom-up SA measure.

Table 6. Mean SA Scores as a Function of Mission in Phase 1 (averaged over TTP)

SA Measure	Mission	
	Defense	Offense
SL	55.5	60.8
SM	34.6	39.3
Sqd	37.3	42.7
Top-Down	39.0	46.0
Bottom-Up	31.8	45.0

[19] Each of two repeated-measures analyses of the percentage retransmission data (one for essential and another for nonessential elements) used two levels of mission and five levels of TTP as independent variables. The only significant effect found was the mission main effect for the nonessential elements data, $F(1,4) = 22.7$, $p < 0.01$.

[20] There were instances of missing data for two measures of SA. There were no SA data for the SL of one squad on four of his 15 trials. There also were no bottom-up questions in the SA test for one vignette-script combination, so each squad was missing bottom-up SA data for this one trial. Estimated values for the missing data were derived using a procedure attributed to Yates by Cochran and Cox (1957. p. 110).

[21] Each test used a repeated-measures design with two levels of mission and five levels of TTP as independent variables. For the SLSA and SqdSA measures, the main effect of TTP was significant [for SLSA, $F(4,12) = 3.8$, and for Sqd SA, $F(4,16) = 3.8$, $p < 0.05$ for both measures]. For the bottom-up SA measure, mission and TTP were significant [$F(1, 4) = 10.0$ and $F(4,11) = 4.4$, respectively, $p < 0.05$ in both cases].

Table 7 shows the effect of TTP on the mean percentage correct SA scores for all SA measures. For all five measures, SA scores tended to be highest on TTP 1 trials and, except for the bottom-up SA measure, the SA scores generally decreased over successively higher numbered TTP conditions. In contrast, for the bottom-up SA measure, the relationship between SA scores and TTP conditions tended to be curvilinear, with mean SA scores highest for those TTP conditions that permitted the fewest (TTP 1) and the maximum (TTP 5) number of SM-initiated radio transmissions. Analyses of the data summarized in Table 7 showed that the effect of TTP was significant for only the SLSA, SqdSA, and bottom-up SA scores. Least-significant difference comparisons of all pairs of SA scores for these three conditions tended to confirm the observations made with respect to Table 7. For the SLSA data, the only comparisons of mean SA score that were significant were those between TTP 1 and both of TTP 3 and TTP 5. For the SqdSA data, the mean SA score for TTP 1 was higher than that found for only TTP 3. Least-significant difference comparisons of all pairs of bottom-up SA scores showed that only the two extreme scores (i.e., those for TTP 1 and TTP 4) were different from each other.

Table 7. Mean SA Scores as a function of TTP in Phase 1 (averaged over mission)

SA Measure	TTP				
	1	2	3	4	5
SL	72.5	67.6	47.1	61.0	42.5
SM	45.5	37.3	31.3	35.4	35.4
Sqd	49.0	41.3	33.5	39.1	36.9
Top-Down	48.3	48.5	33.8	44.3	37.3
Bottom-Up	53.6	34.4	31.9	31.4	40.5

The data in Tables 6 and 7 show that SLSA scores were higher than SMSA scores for both levels of mission and for each TTP condition. This interpretation of the data is supported by the results of a separate analysis of variance.[22] This analysis showed that the grand mean SA score was higher for the SL than for the SMs (58 and 37 %, respectively). The absence of significant interactions of position with mission or with TTP showed that this position effect was consistent over these two other treatments. Finally, one other trend in the SA data needs to be highlighted. It can be seen in both Tables 6 and 7 that the SA measures were generally low, reflecting less than 50 percent correct of the applicable SA Knowledge Test items. The exceptions to this general trend occurred for most of the mean SLSA scores and for the mean bottom-up SA score during TTP 1 trials.

[22] The analysis, which used position as a between-subject source of variance and mission and TTP as repeated-measures sources of variance, found that the position main effect was significant, $F(1, 8) = 18.2$, $p < 0.01$.

RESULTS - PHASE 2

Frequency of Squad Radio Communications in Phase 2

Table 8 summarizes the communications data collected in the squad radio condition of Phase 2.[23] The table presents the mean frequency of communications on both the platoon radio and squad radio for each of the five categories of communication as well as the overall frequencies for providing and requesting communications summed over message categories. These data are shown, after averaging over type of mission for day operations, separately for the day and night visibility conditions. The PL communications data, controlled by the scripted vignettes, are provided in this table to be contrasted and compared with those presented for the SL and SMs. Communications data for message categories that were transmitted one or more times per trial are presented in bold font in the table. As was true for the Phase 1 data, Table 8 shows that substantial levels of communications during Phase 2 occur only for acknowledgement and battlefield information. In addition, since the SMs rarely transmitted any messages on the squad radio, the only useful communications data available from Phase 2 occurred when the SL transmitted radio messages. Consequently, the results presented for the frequency of communications during Phase 2 are limited to those obtained for the SL as he transmitted messages concerned with acknowledgements and battlefield conditions on both his radios.

Frequency of SL Communications during Day Operations

Frequency of communications concerning acknowledgement. The data presented in Table 8 show there was essentially no acknowledgement communications by the SL on the squad radio. Acknowledgement communications by the SL on the platoon radio were more substantial, but with the SL providing many times more acknowledgements to the PL than he requested from the PL. These observations for the frequency of acknowledgement communications were supported by a 2x2x2 repeated measures analysis that examined the effects of radio, action, and mission for SL communications about acknowledgements.[24] The analysis showed additionally that the SL engaged in more acknowledgement communications during defensive than offensive missions when he used the platoon radio (7.7 and 6.6, respectively).

Frequency of communications concerning battlefield information. Table 8 shows that substantial SL communications about battlefield conditions during day operations occurred only when the SL was providing information to other participants; he made essentially no requests for information. However, the predominant type of information provided by the SL varied depending on the radio he was using. When using the platoon radio the SL provided the PL more information about threat conditions than friendly conditions. In contrast, when using the squad radio the SL provided the SMs more information about friendly than threat conditions.

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[23] Analyses of the data for platoon radio transmissions from both the baseline (no squad radio) and the squad radio conditions of Phase 2 showed no significant effects for the frequency of communications between the SL and PL as a function of whether or not the squad radio was also concurrently being used by the SL to communicate with his SMs. Details of this analysis are not further described.

[24] For the SL acknowledgement data, the following effects were found to be significant at the 0.01 level: Radio, action, Radio x Action [$F(1,8) = 74.1$, 258.8, and 55.0, respectively]. Mission and Mission x Radio also were shown to be significant at the 0.05 level [$F(1,8) = 11.3$ and 6.7, respectively].

Table 8. Mean Frequency of Communications in Phase 2 (averaged over mission for day operations)

Day Operations		Platoon Radio		Squad Radio	
Action	Message Category	PL	SL	SL	SM
Provide	Acknowledgment	**6.4**	**10.8**	0.0	0.9
	Direction	0.1	0.1	**1.7**	0.1
	Information (Friend)	**6.9**	**3.1**	**5.1**	0.1
	Information (Threat)	**5.1**	**4.6**	**3.6**	0.3
	Opinion	0.1	0.0	0.0	0.0
	Overall Provide	**18.6**	**18.6**	**10.5**	**1.5**
Request	Acknowledgment	**6.9**	**3.1**	0.1	0.3
	Direction	0.0	0.1	0.0	0.0
	Information (Friend)	**1.4**	0.5	0.3	0.1
	Information (Threat)	0.3	0.5	0.1	0.0
	Opinion	0.0	0.0	0.0	0.0
	Overall Request	**8.7**	**4.2**	0.5	0.3
Night Operations		**Platoon Radio**		**Squad Radio**	
Action	Message Category	PL	SL	SL	SM
Provide	Acknowledgment	**3.2**	**8.9**	0.1	0.3
	Direction	0.1	0.3	**2.8**	0.3
	Information (Friend)	**9.5**	**3.1**	**6.1**	0.4
	Information (Threat)	**4.3**	**2.0**	**2.8**	0.0
	Opinion	0.0	0.0	0.0	0.0
	Overall Provide	**17.1**	**14.2**	**11.9**	0.9
Request	Acknowledgment	**3.0**	**1.7**	0.0	0.3
	Direction	0.0	0.0	0.0	0.0
	Information (Friend)	**1.6**	**1.1**	0.6	0.1
	Information (Threat)	0.0	0.4	0.4	0.0
	Opinion	0.0	0.0	0.0	0.0
	Overall Request	**4.6**	**3.4**	**1.0**	0.4

Note. Data for the PL are presented for comparison with other data in the table. Cells containing frequencies of one or more transmissions per trial are presented in bold font.

Table 9 shows the effects of the mission treatment when it is factored into the Phase 2 results just described. These data show that differences in the types of information the SL provides to the PL and SMs occurred principally on defensive trials. Specifically, on defensive trials the SL provided the PL more information about threat than friendly conditions and, conversely, he provided the SMs more information about friendly than threat conditions. On offensive mission trials, the SL tended to provide about equal amounts of friendly and threat information to the PL and SMs. These observations were supported by an analysis of variance similar in design to that performed for acknowledgement communications, but with the type of

information (friendly and threat) added as a fourth repeated-measures variable.[25] These Phase 2 results for the action of providing information about battlefield conditions are similar to those reported for the Phase 1 results averaged over TTP conditions.

Table 9. Mean Frequency of Communications about Battlefield Conditions in Phase 2

Action by Information Type	Platoon Radio				Squad Radio	
	PL		SL		SL	
	Defense	Offense	Defense	Offense	Defense	Offense
Provide						
Friend	**7.7**	**6.2**	**2.6**	**3.7**	**6.3**	**3.9**
Threat	**4.0**	**6.1**	**6.9**	**2.3**	**3.0**	**4.2**
Request						
Friend	**1.8**	**1.1**	0.4	0.6	0.3	0.3
Threat	0.6	0.1	0.3	0.7	0.1	0.1

Note. Data for the PL are presented for comparison with other data in the table. Cells containing frequencies of one or more transmissions per trial are presented in bold font.

Direct comparison of Phases 1 and 2 for communications about battlefield conditions. Since Phase 2 day operations trials were conducted using a subset of the scripted vignettes used in Phase 1, the data collected during Phase 2 day operations were compared directly to those obtained during the comparable TTP 1 condition in Phase 1. These comparisons were evaluated in an analysis that used phase as a between-subjects variable and all other independent variables as repeated-measures variables. The analysis showed the main effect of phase during comparable TTP 1 trials was moderated by an interaction with action and a four-way interaction with radio, information type, and mission.[26] The SL more frequently requested battlefield information in Phase 1 than Phase 2 (1.8 and 0.3, respectively). This difference was largely attributable to the SL requesting threat information from the SMs on defensive missions during Phase 1 but not during Phase 2 (3.4 and 0.1 requests per trial, respectively).

Frequency of SL Communications during Night Operations

Examination of the data presented in Table 8 for the frequency of radio communications during Phase 2 night operations revealed many trends in the data similar to those shown for the Phase 2 day operations. The frequency of acknowledgement communications were negligible on the squad radio, and those on the platoon radio were mostly instances of the SL providing

[25] For the SL frequency of communications about battlefield conditions, the following effects were significant: as shown in Table 8, action, Radio x Information Type, Radio x Action x Information Type [$F(1, 8) = 202.9$, 13.0 (both with $p < 0.01$) and 9,3 ($p < 0.05$), respectively]. With mission added as an independent variable, the following effects were significant: mission, Action x Mission, Radio x Information Type x Mission, and Radio x Action x Information Type x Mission [$F(1,8) = 5.7$, 8.6 ($p < 0.05$ in both cases), 43.9, and 27.9 ($p < 0.01$ in both cases), respectively].

[26] The following significant effects involving Phase on the frequency of communications about battlefield conditions were found for the SL using both his radios: phase and Action x Phase (both with $p < 0.05$) as well as Information Type x Mission x Radio x Phase (with $p < 0.01$) [$F(1,12) = 6.9$, 5.0, and 10.5, respectively].

acknowledgements to the PL.[27] Analyses of the night operations data for the SL frequency of communications about battlefield conditions showed that all possible main and interaction effects were significant.[28] As indicated in Table 8, there were few SL requests during night operations for battlefield information on the platoon radio, and practically none on the squad radio. When the SL provided battlefield information during night operations, it was more likely about friendly than threat conditions, especially on the squad radio.

Direct comparison of day and night trials in Phase 2 for communications about battlefield conditions. The data from the night offensive mission trials were compared directly to the data from daylight offensive mission trials. Several significant effects involving the visibility factor were found.[29] These results are summarized in Table 10. The major factors accounting for the differences in communications as a function of visibility conditions was the higher level of SL communications on the squad radio about friendly conditions during night than day trials and about threat conditions during day than night trials. These effects parallel the frequencies of corresponding transmissions shown for the PL communicating to the SL on the platoon radio.

Table 10. Mean Frequency of Information Communicated during Day and Night Trials

Action by Visibility Condition	Platoon Radio				Squad Radio	
	PL		SL		SL	
	Friend	Threat	Friend	Threat	Friend	Threat
Provide						
Day	**6.2**	**6.1**	**3.7**	**2.3**	**3.9**	**4.2**
Night	**9.5**	**4.3**	**3.1**	**2.1**	**6.1**	**2.8**
Request						
Day	**1.1**	0.1	0.6	0.7	0.2	0.1
Night	**1.6**	0.0	**1.1**	0.4	0.6	0.4

Note. Data for the PL are presented for comparison with other data in the table. Cells containing frequencies of one or more transmissions per trial are presented in bold font.

[27] An analysis of the SL frequency of acknowledgement communications used radio and action as repeated-measures variables. This analysis showed that both main effects and the Radio x Action interaction were significant at the $p < 0.01$ level [$F(1,8) = 35.1$, 11.4, and 11.6, respectively].

[28] An analysis of the frequency of SL communications about battlefield conditions during night operations used radio, action, and information type as repeated-measures variables. The following effects were shown to be significant at the $p < 0.01$ level: radio, action, information type, Radio x Action, and Action x Information Type [$F(1,8) = 20.8$, 150.8, 60.8, 15.5, and 30.4]. The interaction Radio x Information Type and Radio x Action x Information Type were significant at the $p < 0.05$ level [$F(1,8) = 5.6$ and 9.7, respectively].

[29] An analysis of the frequency of SL communications as a function of day and night trials used visibility conditions, radio, action, and information type as repeated-measures sources of variance. The following effects were significant: Visibility x Radio, Visibility x Information Type, Visibility x Radio x Information Type, and Visibility x Radio x Action x Information Type [$F(1, 8) = 10.0$ ($p < 0.05$), 17.1 ($p < 0.01$), 6.3, and 6.9 ($p < 0.05$ in both cases), respectively].

Retransmission of Scripted Message Elements in Phase 2

The mean percentage retransmission of message elements that were essential and nonessential for correctly responding to the SA Knowledge Test is presented in Table 11, separately for the defensive and offensive mission conditions of the Phase 2 day trials and for the offensive mission trials of the Phase 2 night trials. Analyses of these data showed two significant effects. First, the percentage retransmission was higher for essential message elements only during day defensive mission trials than day offensive mission trials.[30] Second, the SL retransmitted a higher percentage of essential elements than nonessential elements during daylight trials only (averaged over mission type, 85.6 and 72.3 %, respectively).[31]

Table 11. Percentage Retransmission of PL Message Elements by the SL in Phase 2

Message Element	Visibility by Mission		
	Day		Night
	Defensive	Offensive	Offensive
Essential	98.1	73.0	65.3
Nonessential	82.0	62.6	68.4

Measures of Situation Awareness in Phase 2[32]

SA in the Baseline and Squad Radio Conditions

Table 12 gives the mean SA scores for offensive and defensive mission conditions during day operations and for the offensive mission condition during night operations, separately for the baseline and squad radio conditions. Based on the results reported by Redden and Blackwell (2001) it was expected that SA scores would be higher when the squads were able to use the Squad Radio than when they could not do so. While the trend of the results shown in Table 12 would support the earlier findings, analyses of these data failed to yield any significant effects that can be attributed to the baseline and squad radio conditions.

Other Findings Related to SA Measures

SA measures for the SL and SMs. Table 12 shows that SLSA scores were consistently higher than SMSA scores. Analyses were performed separately for the daylight trials using

[30] Each of two repeated-measures analyses of the percentage retransmission data (one for essential and another for nonessential elements) used mission as an independent variable. The only significant effect found was the mission main effect for essential elements data, $F(1,8) = 18.1$, $p < 0.01$.

[31] For the retransmission of message elements as a function of mission and type of element, only the main effect of the type of message element was significant, $F(1, 8) = 10.7$, $p < 0.05$.

[32] There were missing SA data in Phase 2. Two squads were missing a top-down SA score during night operations. Estimated values for the missing data were determined using the procedure described by Cochran and Cox (1957, p. 110).

mission and squad communication conditions as repeated measures and for the night trials using squad communication conditions as a repeated measure. Both analyze the SL and SM positions as a between-subjects measure. These analyses yielded significant findings for only the main effect of the SLSA and SMSA scores.[33]

Table 12. Mean SA Scores in Phase 2

	Baseline (no Squad Radio)			Squad Radio Communication		
	Day	Day	Night	Day	Day	Night
SA Measure	Defensive	Offensive	Offensive	Defensive	Offensive	Offensive
SL	48.3	49.4	41.7	56.7	52.8	50.9
SM	36.7	29.3	27.0	42.3	30.5	33.8
Squad	38.0	31.6	28.6	43.9	33.0	35.7
Top-Down	37.4	30.4	19.8	43.4	33.8	22.9
Bottom-Up	24.1	35.2	38.8	30.9	22.2	41.6

SA as a function of mission for day operations. Table 12 shows that the mean SA scores during day operations were higher for defensive missions than they were for offensive missions. This observation was generally supported by analyses that used mission and squad communication conditions as repeated measures. These analyses showed that the only significant effects were the mission main effect for the SMSA, SqdSA, and top-down SA measures.[34]

SA as a function of day and night visibility. The data presented in Table 12 for offensive missions only show no consistent trends as a function of day and night conditions. Separate analyses were performed of the five SA scores, each using visibility and squad communication conditions as repeated-measures variables. These analyses showed that the only significant effect was for the main effect of visibility for the top-down SA measure.[35] The mean top-down SA score averaged over squad communication conditions was higher for day than night operations (31.1 and 21.4 %, respectively).

SA measures for the top-down and bottom-up items on the SA Knowledge Test. There are no consistent trends for the top-down and bottom-up SA scores shown in Table 12. Separate analyses for the four day trials and the two night trials each used these two SA measures as a repeated-measures variable. These analyses found that the only significant effect occurred for SA measures during night trials. The mean bottom-up SA measure was higher than the mean top-down SA measure (averaged over squad communication conditions, 40.2 and 21.4 %, respectively).[36]

[33] The main effect of position (SLSA and SMSA) on SA measures was significant for both day and night trials, $F(1,16) = 15.0$ ($p < 0.01$) and 6.8 ($p < 0.05$), respectively.
[34] Mission was significant at the $p < 0.01$ level for SMSA and SqdSA [$F(1,8) = 12.5$ and 12.4, respectively] and for top-down SA at the $p = 0.05$ level [$F(1, 6) = 5.9$].
[35] Mean top-down SA scores were higher during day than night operations, $F(1,6) = 8.4$, $p < 0.05$.
[36] The main effect due to top-down SA and bottom-up SA during night trials was significant [$F(1, 6) = 37.5$, $p < 0.01$)].

Direct comparison of SA measures obtained in Phases 1 and 2. Separate analyses were applied to each of the five SA measures obtained from the Phase 2 day trials on which the squad radio was used (shown in Table 12) and Phase 1 TTP 1 trials (shown, averaged over mission, in Table 7). Phase was a between-subjects variable and mission a repeated-measures variable for all the analyses. While each of these five SA scores was higher in Phase 1 than Phase 2, the analyses show that the main effect of phase was significant for only the SqdSA scores (49.0 and 38.4 %, respectively) and the bottom-up SA (53.6 and 32.6 %, respectively).[37]

DISCUSSION

Measures of Radio Communication

Efficacy of the Radio Communication Data Collection Form

The results clearly demonstrated the value of the data collection form used for obtaining information about the frequency and content of squad radio transmissions. The data provided by using this form were meaningfully sensitive to communications on two different radios, by communicators in duty positions representing different tactical responsibilities and scopes of interest and influence, the separate action of providing and requesting radio input, and different types of battlefield information. The similarity of the pattern of results found for the frequency of communications for the two different samples of participants during a common set of exercises in Phases 1 and 2, as well as the commonality of findings for a single set of participants for quite different day and night vignettes in Phase 2, contribute to our belief that the method for assessing radio communications is both useful and reliable.

The results presented for the frequency and content of communications permit discussion of several interrelated factors that will likely help to determine important parameters, as well as the ultimate consequences, of radio communications among members of small, lower-echelon units. Each of these factors will be discussed in subsequent labeled paragraphs, beginning with two that were reported previously.

Correspondence with and Enrichment of Results Previously Reported

Communications concerning acknowledgement. It was reported previously that communications concerned with acknowledgements were the most frequent single type of radio transmission (DBBL & MCWL, 1999; Phelps & Kupets, 1984). The results of this experiment confirm that finding for communications on the platoon radio but not for communications on the squad radio. In fact, requesting and providing acknowledgements occurred quite infrequently on the squad radio. A logical explanation for the diverse findings can be attributed in part to the physical dispersion of the communicators. Radio communications in the previous studies and on the platoon radio in this research were initiated by infantrymen in different locations on the

[37] The main effect of phase was significant for the SqdSA and bottom-up SA measures [$F(1,12) = 4.7$ ($p = 0.05$) and 11.4 ($p < 0.01$), respectively].

battlefield. Hence, since there is a need to verify that the intended recipient of a communication is present and prepared to receive a message, it was necessary for the communicators in these situations to request and provide acknowledgements. In the present research, the various members of the squad were generally in line of sight of and in close proximity to one another. Therefore, it was not necessary for them to seek acknowledgements over the squad radio before transmitting a radio message.

Mission-related communications. It was reported previously that the frequency of communications about threat conditions was higher during defensive missions than during offensive missions (DBBL & MCWL, 1999). The present research generally confirms that finding but enriches the effect by (a) addressing concurrently the effects separately for SLs and SMs and (b) examining it jointly as a function of how many SMs are permitted to transmit messages. The frequency of communications was higher on defensive missions than on offensive missions for the SL whether he was transmitting threat messages to the PL, requesting threat information from the SMs, or providing friendly information to the SMs. These results may reflect the responsibilities and interests of the SL. Alternately, they may reflect merely the fact that there was more time available and more opportunity for the SL to communicate on the squad radio during the longer duration and generally slower operational tempo of the defensive mission trials than there was on the offensive mission trials. In contrast, the effect of mission type on communications of the SMs varied with the type of information being transmitted. The frequency of transmitting threat information was higher on defensive missions than on offensive missions but the frequency of communications about friendly conditions was higher on offensive missions than on defensive missions. The latter effect was greatest when all SMs were permitted to communicate with all other SMs, to include those in the other fire team. As will be discussed below, the mission-related results found for the SMs may be related to the issue of what type of information is more critical to share on different types of missions.

Upward and Downward Directed Radio Communications about Battlefield Conditions

As a result of the methods employed, the frequencies of downward directed communications by the PL to the SL and by the SL to his SMs were determined principally and respectively by (a) the scripts that determined the PL transmissions that provided information to and requested information from the SL, and (b) the requirement for the SL to retransmit (i.e., provide) to the SMs the scripted information he received from the PL. In contrast, the frequency of upward directed communications, as well as the frequency of downward directed communications in which the SL requests information from his SMs were not prescribed by the experimental method. The SL generally and the SMs in the TTP 2, TTP 4, and TTP 5 conditions were relatively free to determine what and when they would provide information to or request information from other participants.

The results obtained in this experiment show that the frequency of upward and downward directed communications was affected differently by the type of information being transmitted. The results show that the frequency of communications was higher for information about friendly conditions than for information about threat conditions in the scripted downward flow of information from the PL to the SL and, though the SL, to the SMs. In contrast, the results also show that the frequency of information being provided in upwardly directed transmissions and

the frequency of information the SL requested from the SMs was greater when it was about threat conditions than about friendly conditions.

These findings make sense in the context of the simulated combat conditions that characterized experimental trials. It is reasonable to expect that the PL would be in a position to more frequently provide information about friendly conditions than threat conditions. The PL was in a relatively remote location vis-a-vis the simulated combat and he generally had greater access to information about the friendly force disposition than about the threat force disposition. On the other hand, it also is reasonable to expect that the upward flow of information across both radios and the SL requests for information from his subordinates would be more concerned with information about threat than the friendly conditions since the squad was in contact with a hostile force.

The matter of echelon differences in what is considered critical information was addressed by Redden and Blackwell (2001). They showed that the PLs and SLs rated the criticality of information related to command and control issues higher than did the SMs. This information includes that which identifies the disposition of both friendly and threat elements in locations at varying distances from the immediate combat environment of the squad. On the other hand, these authors reported that SMs were only concerned with information about the threat elements in their immediate environment. This research produced one finding that is out of line with the previous results. Specifically, that the SMs in Phase 1 communicated more frequently about friendly conditions on offensive missions than they did on defensive trials and that they did so principally when they could communicate with SMs in the adjacent fire team. It is suggested that this finding may be due to the SMs greater concern with the disposition of friendly elements during offensive than they are during defensive missions. There is less line-of-sight visual contact and more uncertainty about the exact location of other SMs when the squad is on the move and at varying distances from one another during the assault and subsequent consolidation phases of an offensive mission than there is during the fixed-position defensive missions.

Impact of Visibility on Squad Radio Communications

Redden and Blackwell (2000, 2001) discussed the increased importance of squad radio communications during periods of limited visibility. They specifically considered the matter of reduced visibility under conditions of nighttime operations and during phases of a mission characterized by large dispersion among squad members. The results of this research found no difference in the frequency or the content of radio communications between day and night operations. However, in this experiment, direct comparisons between data collected during day and night operations were confounded by many uncontrolled variables. The results did show that the highest level of communications by the SMs occurred when they were able to communicate with SMs located in teams other than their own. The results showed also that SL requests for information from the SMs was relatively low in Phase 1 even though the SMs were permitted to use the radio in all but the TTP 1 condition. Even in the TTP 1 condition of Phases 1 and 2, when they could not use the squad radio, the SMs could have responded to a SL request for information by using visual as opposed to vocal means to communicate. The absence of SL requests for information on the squad radio is probably a result of fact the vignettes used in the experiment allowed the SL to be in almost constant line of sight with and in close physical

proximity to all his SMs. He and his SMs generally were in position to make the exact same observations about the immediate combat environment. Consequently, the SL would not have to use the squad radio to request that the SMs independently provide information on their personal observations.

Impact of Radio Communications on How Information is Processed

The requirement for processing information transmitted on the squad radio most likely impact how information is processed as well as how much and what particular types of information is communicated. Unfortunately, research results are quite limited for addressing the issue of how information-processing methods might vary and the consequences of different processing methods. The results of this research showed that more information flowed to the SL from the PL and from the SMs (when the latter could transmit messages in Phase 1) than flowed from the SL to the PL and SMs. This particular result suggests that the SL was placed in a position in which he was required to select, filter, consolidate, and otherwise process the information he received over each of his two radios before he decided what to communicate over either radio. The SL could easily experience conflicting communication requirements as a consequence of the confluence of (a) his own and his SMs' interest in acquiring information about the current and close threat conditions and (b) the PL scripted input about future conditions and his higher frequency of providing information about friendly conditions than about threat conditions. These conflicting requirements for processing information would be most pronounced when the amount of information to be processed was high.

Summary of the Measures of Radio Communications

The results obtained from this research show that there is a need to further examine the various parameters of squad radio communications. More information is required about alternate procedures of squad radio use to establish guidance on how they might be most effectively used, as well as the consequences of different use procedures. The results show that the guidance will need to consider not only the mission in which the radio will be used but also the type (and criticality) of information that might be communicated, the direction of information flow, and the areas of interest and influence driven by the echelon of the communicator. Furthermore, as described subsequently, the information processing requirements and decisions concerning how information should be processed also impact measured levels of SA.

Based on the experiences acquired and the results obtained from using the data collection form developed for this research, recommendations are offered to address each of the four following sets of issues during future research.

Types of communication. The granularity of information type or category needs to be further refined from that which merely established whether the message contains information about friendly or threat conditions. It is important to take advantage of whatever task analyses are available for the missions to be simulated and to establish the means necessary to tabulate separately information about friendly conditions, threat conditions, civilians and other "naturally" occurring elements on the battlefield, as well as possible interactions among these separate elements.

Source and intended destination of communications. Methods need to be established to tabulate both the source and the intended recipient (or, at a minimum the lateral versus upward directed flow) of communications initiated by the SMs. This is particularly important if more attention is to be paid to bottom-up and horizontal communication flow. Methods also need to be established to identify the intended destination of downward communications initiated by the SL if these communications are directed to specific members of the squad.

Timing of radio communications. If possible, say, via an electronic data collection device, it is desirable to get a time-stamp on the transmission of radio messages. Information on the timing of transmissions would permit clusters and sequences of related communications to be identified and allow the relationship between communications and events occurring on the battlefield to be better established.

Non-radio and non-verbal communications. It is desirable to develop methods to record non-radio verbal and non-verbal communications between members of the squad. Collecting this type of information would most likely require that the data collector be in a position to directly observe the activities of the SL and the SMs. Alternatively, activities of members of the squad could be videotaped for subsequent viewing and scoring. Information on the occurrence of non-radio communications is needed to answers questions such as the following. Under what conditions is use of the squad radio essential? How should a squad radio be used to augment other forms of communication, and vice versa? How can squad radio communications be used to signal the need for specific types of non-radio communications, and vice versa?

Measures of Situation Awareness

The Relationship between Squad Radio Communications and Squad SA

Redden and Blackwell (2001, 2001) developed a method to evaluate the impact of squad radio communications on SA in a field environment that was both direct and simple in conception. Their hypothesis was based on the belief that a PL would be in a position to acquire battlefield information that would be important, if not critical, to achieving success in ongoing military operations. If this were true, radio communications from the PL to his SLs and through them to their respective SMs would permit both the SLs and the SMs to develop the SA required to achieve mission success. Measures of SA would be based on each participant's knowledge of critical information contained in the PL transmissions. The results of their two studies that examined the mean level of SA in each experiment, pooled over all participants, supported their hypotheses and their methodology.

The research described in this report reanalyzed the SA data collected by Redden and Blackwell (2001) to derive five different squad-level measures of SA. The derived data were comprised of the SA scores of each SL for one set of data, the mean SA scores averaged over all SMs in each squad for another, and the mean SA scores averaged over all members of each squad including the SL for three other sets of data. The analyses of these derived SA data only partially supported the results reported by Redden and Blackwell (2001). Each of the five sets of

squad-level SA scores derived for this report from their Phase 1 data showed, as their data did, that the squad-level measures of SA were highest for TTP 1. However, the derived SA scores associated with TTP 1 did not differ statistically from the derived SA scores associated with two or more of the other TTP conditions. Each of the sets of squad-level SA scores derived for this report from their Phase 2 data suggested trends for higher levels of SA when the SL was able to use the squad radio to communicate with his SMs than when he could not. This was the result reported by Redden and Blackwell (2001). However, these trends in the derived data were not statistically significance. These two sets of results for the derived measures of SA are mutually supportive. In Phase 1, there was no clear evidence that SA is systematically affected by whether or not and to what extent the SMs transmit messages on squad radio. In Phase 2, the absence of a significant difference between the baseline (no squad radio) and the squad radio conditions suggests that SA may not be systematically affected by whether the SL is permitted to use the squad radio to retransmit PL messages to, and otherwise communicate with, his SMs.

Other results of this fine-grained reanalysis of the SA data collected by Redden and Blackwell (2001) also challenge the assumptions and the results reported by these investigators. For example, if the information transmitted by the PL to the SL were important for the development of SLSA, then variations in the amount of this information that are retransmitted over the squad radio by the SL should be directly related to measures of SMSA and SqdSA. This prediction was not generally supported by the results. Measures obtained in this research for the percentage of PL scripted message elements retransmitted by the SL to his SMs did not consistently covary across various independent variables with any derived measure of SA. For example, while the percentage of PL scripted message elements was higher in both phases of the experiment for defensive mission trials than for offensive mission trials, there was no consistent relationship between derived measures of SA and the type of mission. Furthermore, while the mean SLSA score on the SA Knowledge Test was reasonably high in both Phase 1 and Phase 2, the mean SA scores derived for the SMs and the squad as a whole were generally low (i.e., 40 % or less correct). This result was reported also by Redden and Blackwell (2001). They claimed that the result suggests that the SMs were not adequately aware of critical information provided by the PL and needed by the SMs to successfully accomplish their objectives.

The results described in this report do not lend strong support for and sometimes conflict with the principal hypothesis of the Redden and Blackwell studies. The difference in results from this research and their studies is at least in part a function of the fact that more powerful statistical tests were used in the earlier studies than were used in this research.[38] More importantly, however, the results of this detailed analysis of radio communications and SA

[38] By using the average SA score over all participants in each of their studies, Redden and Blackwell maximized the sample size used for their test statistics and hence the power of their tests for finding differences in mean SA scores. By using squad-level data for statistical tests in this research, sample size was reduced to the number of squads investigated, and the power of the statistical tests was reduced accordingly. However, the authors of this report argue that their use of squad-level data (and hence a smaller sample size) was more correct than Redden and Blackwell's use of individual soldier data as a unit of analysis for SA data. The driving hypothesis of this research is that the use of squad radios will increase the SA of infantrymen in a squad, not the SA of the all infantrymen averaged over an entire experiment. Furthermore, Redden and Blackwell, in both of their reports, noted that critical information requirements, that are the basis for their estimates of SA, were not the same for leaders of a squad as for other squad members. Pooling over SLs and SMs to derive an overall average SA score ignores this important difference in the criticality of information for different participants.

underscore the importance of several possible confounding issues discussed by Redden and Blackwell in both of their studies. In addition, as described below, the tests used to measure of the infantryman's knowledge of critical events may not be adequate and, therefore, may not accurately estimate the SA of the infantrymen. Each of three issues raised by Redden and Blackwell and the results of this research that address them are summarized in subsequent labeled paragraphs.

Squad radio effects on SA and visibility among members of the squad. In both of their studies, Redden and Blackwell (2000, 2001) report results to support their conclusion that squad radio communications have a more positive effect on SA during nighttime operations than day time operations and when the infantrymen were widely dispersed on the battlefield. Their interpretation of these findings was that when the participants were unable to see each other and communicate using hand and arm signals, they would have to rely on other means (such as the squad radio) to share information. While the rationale for their conclusion may be logically correct, this research found no empirical data to support it, at least in terms of daytime and nighttime operations. First, this research found no effect of the use of squad radios on SA during day and night operations when only data from offensive mission trials were used for the comparison. The results reported by Redden and Blackwell (2001) confounded the effects of mission type and day-night visibility. Second, this research found no main effect of, and no interaction effects that incorporate, the day-night visibility treatment on the frequency of squad radio communications.

Squad radio effects on SA and information overload. Redden and Blackwell (2001) posited that messages communicated on the squad radio in the TTP 1 condition were limited to those likely to be critical to the conduct of the mission. In contrast, they argue that many of the additional messages communicated by SMs in the other TTP conditions used in Phase 1 of their experiment were probably not critical. They concluded that the greater amounts of communication on the squad radio for these other TTP conditions increased the likelihood for cognitive overload – presumably for all infantrymen in the squad but especially the SL who had to handle communications on two different radios. The reduced opportunity for cognitive overload in the TTP 1 condition was used Redden and Blackwell to explain their finding of higher SA in the TTP 1 condition than in each of the other four TTP conditions.

This research, like their study, has no empirical data that can address the accuracy of their claim that SMs transmit non-critical information. This research found no evidence of radio transmissions that were unrelated to the mission. However, this research did produce data suggesting other sources of cognitive overload than that presumably contributed by the SMs. These include (a) the frequency and (b) the content of scripted communications of the PL, and (c) the requirement that the SL retransmit these scripted messages to the SMs. The frequency of communications on the platoon radio was high both in an absolute sense as well as relative to that on the squad radio. It is reasonable to conclude that the SL had to expend effort and time to first receiving and then retransmitting scripted messages from the PL. We contend that the high frequencies of communications by the PL can and probably does cause the SL to experience cognitive overload, irrespective of whether the SMs are permitted to initiate transmission over the squad radio. Furthermore, since the SL does retransmit most of the scripted information he received from the PL to the SMs, the SMs may likewise have experienced cognitive overload,

even if they were not permitted to initiate radio transmissions themselves. Instances of cognitive overload may cause the SL and particularly the SMs to stop attending to or to otherwise block out radio transmissions that contribute to the overload. This action would deprive the participants of the scripted critical information transmitted by the PL and, therefore, lower their performance on the SA Knowledge Tests.

Squad radio effects on SA and echelon differences in perceived criticality of battlefield information. An examination of the content of scripted PL radio transmissions to the SL was shown to frequently addresses battlefield conditions that were both temporally and spatially peripheral to the immediate informational needs of the squad. For example, upward to 50 percent of the content of the scripted messages given in Appendix Table A-1 was not of immediate value to the combat mission already being executed (e.g., the location of leaders one to two echelons higher than the squad). Furthermore, the frequency of information messages actually provided by the PL during a trial showed that more were about friendly conditions was about threat conditions. Consequently, the communications of the PL may have served more as a distraction than an aid to improving the SA required by the squad to achieve effectiveness in the ongoing combat operation.

In contrast, the data showed that when permitted to initiate communications, the SMs provided information about threat conditions more than they did information about friendly conditions. These data on communication flow support the Redden and Blackwell (2001) conclusion that the SMs were concerned only with the location and status of the threat. Our data also show that the SL was more apt to request from his SMs information about threat conditions than information about friendly conditions. In addition, except for the Phase 2 night operations condition, the SL was more likely to provide to the PL information about threat conditions than friendly conditions. These latter findings suggest the SL, like his SMs, was more interested in the status of the threat than the status of friendly elements, at least during the execution of a mission.

Finally, based on our crosswalk between critical items on the SA Knowledge Test and the information contained in the scripted messages provide by the PL, it is safe to conclude that the SA Knowledge Test was heavily biased toward knowledge contained in the top-down scripted messages. Hence, the test was biased against knowledge that the SL and the SMs could have obtained from their observations of the immediate battlefield environment. This latter source of critical battlefield information is captured in the bottom-up SA measure developed for this research. The high levels of bottom-up SA that were achieved when all SMs were permitted to transmit messages to all other members of the squad suggest that in addition to considering the information requirements of different echelons, there is a need to consider more than one source of critical information and more than one measure of SA. Clearly, the SMs at the forward edge of a battle are an indispensable source of critical information for all infantrymen involved in the battle. Of course, disciplined squad radio procedures would have to be in place to minimize unnecessary amounts of communication. If communications are restricted to only essential information, the upward directed inputs of the SMs should serve to augment the SA of soldiers and leaders at higher echelons and in adjacent units. Future research therefore ought to capture changes in the SA of soldiers and leaders in echelons higher than the squad, those who are in a position to receive relevant battlefield information from the bottom up.

Summary of the Measures of SA

Redden and Blackwell (2000, 2001) concluded that the field-based free-play exercises they used in the first of their experiments and, more particularly, the more controlled scripted vignettes they used in their second experiment permitted SA to be evaluated in a realistic natural environment. They also conclude that the questionnaire assessment of knowledge technique proposed by Endsley provided a useful measure of SA. This research found evidence to support important conclusions. The results of this research also support the recommendations for future research that were proposed by Redden and Blackwell. For example, they suggest that the matter of optimal squad radio procedures (or TTPs) needs to be reexamined in future research because the one they designated as the best in their second experiment might not be the best for all types of scripted vignettes. In particular, they noted that the optimal squad radio procedure for maximizing SA scores might be quite different in vignettes that had great physical dispersion among the SMs. They also suggest that squads should be investigated that are less well trained and disciplined than the Rangers they used in their second experiment. They indicated that Rangers were better trained for silent communication techniques and hence would not need to rely on vocal communications as much as other infantrymen to develop useful levels of SA. Finally, Redden and Blackwell (2001) recommend that future research needs to better tailor SA Knowledge Test items for different echelons. The results of this research support each of these recommendations.

In addition, the results of this research also lead to the recommendation that future research on the relationship between squad radios and SA carefully consider various parameters of squad radio usage during military operations. It clearly is insufficient to merely compare the SA scores of infantrymen who use squad radios to communicate with the SA scores of infantrymen who do not use squad radios to communicate. This research showed that squad radio usage differs for SLs and SMs. The different frequencies and content of communications by SLs and SMs vary significantly as a joint function of the type of mission being executed and the type of information being communicated. While the small sample size used for this research prevented meaningful direct comparisons of the measures obtained for SA and those obtained for the frequency and content of radio communications, it was possible to show that the experimental conditions that affect SA also affect squad radio communications. Finally, the different sets of SA scores derived for this research from the SA data collected by Redden and Blackwell (2001) strongly suggest that future research needs to examine more than just the overall average levels of SA obtained.

Redden and Blackwell (2001) noted that in the future SA Knowledge Test items should be tailored differently for different echelons. We agree, but add that the test must be tailored to other contingencies as well. The factors that constitute good measures of SA for leaders of a squad and their subordinates are not necessarily or appropriately the same. At a minimum, SA measures need to reflect possible differences in the SA of these two classes of participants as well as the SA knowledge each might derive from the top-down transfer of critical information and that they might derive from bottom-up and lateral transfer of critical information.

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APPENDIX A

INFORMATION RELATED TO THE EXPERIMENTAL METHOD

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Table A-1. Example of Scripted Vignette (adapted from Redden & Blackwell, 2001)*

TIME (Minutes)	Squad Activities	Platoon Leader Radio Transmissions	OPFOR/COB Status/Actions
H HOUR	Attack From Building C1 to C2	1. PL located West end of C1	- OpFor in steeple - 1 OpFor in room 1/C2 - 1 OpFor in room 3/C2 - 3 OpFor in C4 (window 2-6, 2-7 with weapon) - 2 COBs in C3 - OpFor room 1 & 3 fight to death - All doors open in C2 - Dead OpFor in room 3 will have a map with the OpFor positions on him/her
+1	Initial attack – smoke deployed	2. INSUM: two motorized vehicles reported vicinity Pinetree & Hourglass road 3. RPT: HIP Helicopter reported 5K East of McKenna moving South West	- Steeple Marksman exposed – shoots targets of opportunity
+1-3	Move from Building C1 to C2	4. Company CCP co-located with Platoon CCP/POW 5. A Company under fire from church steeple 1 KIA, 1 WIA 6. Report: Support squad has OpFor in steeple under fire	- 2 COBs run from C3 to C4 into door A - OpFor exposed in NE window room 3, C2, when Rangers enter building
+3-5	Move from Building C1 to C2	7. MSG: 3 OpFor seen in C4 (window 2-6 & 2-7) 8. Insum Doctor believed to be in C4. 9. OpFor seen in NE window building C2	- Steeple marksman taken out - 3 OpFor in C4, window 2-6 & 2-7, fire on ExFor
+5-10	Prepare/ enter Building C2	-- Request SITREP if support squad does not report 10. MSG: 2 COB's seen running from C3 to C4 11. RPT: HIP landed East end of McKenna Airstrip, debarking troops	- 2 OpFor in C2 fight to the death
+10-15	Secure Objective	12. 3rd squad 2 WIA to booby traps 13. Platoon leader has moved to C3 to evacuate causalities 14. A Company reports doctor seen in B1 15. Motorized vehicles turning east on Hourglass road -- Request ACE report	

* A list of acronyms and abbreviations is given on the next page.

Acronyms and Abbreviations Used in Sample Vignette

ACE report ..... Ammunition, casualty, and equipment status report
B1 ..... Designator of a building at the McKenna MOUT site
C1, C2, C3, C4 ..... Designator of a series of 3 building at the McKenna MOUT site
CCP ..... Casualty collection point
COB ..... Civilian on battlefield
HIP ..... Type of former Soviet Union helicopter
INSUM ..... Intelligence summary
KIA ..... Killed in action
MSG ..... Message
NE ..... Northeast
OpFor ..... Opposing Force
PL ..... Platoon leader
POW ..... Prisoner of war
RPT ..... Report
SITREP ..... Situation report
WIA ..... Wounded in action

Table A-2. Post-TTP Training Survey and Results

Post-TTP Training Survey

---

1. Please circle your duty position:

Platoon Leader

Platoon Sergeant

Squad Leader

Team Leader

Team Member

2. Please circle the procedure which is closest to how YOUU have used the Soldier Intercom in the past:

TTP#1

TTP#2

TTP#3

TTP#4

TTP#5

Cannot Decide

Don't Know

None of the Above (Please describe your procedure):

Results of the Survey

Number of Participants Providing Each Response Alternative by Duty Position

Duty Position	TTP#1	TTP#2	TTP#3	TTP#4	TTP#5	CD	DK	NOA
Platoon Leader					1			
Platoon Sergeant								
Squad Leader					4			1
Team Leader				2	9			
Team Member				5	16		2	1

Table A-3. Order of Experimental Conditions Within and Across Squads in Phase 1 (adapted from Redden & Blackwell, 2001)

Trial per Squad	Squad																			
	1				2				3				4				5			
	Trial	TTP	Vignette	Script	Trial	TTP	Vignette	Script	Trial	TTP	Vignette	Script	Trial	TTP	Vignette	Script	Trial	TTP	Vignette	Script
(Practice)	1 (p)				2 (p)				3 (p)				4 (p)				5 (p)			
1	6				7				8				9				10			
2	11				12				13				14				5			
3	16				17				18				19				20			
4	21				22				23				24				25			
5	26				27				28				29				30			
6	31				32				33				34				35			
7	36				37				38				39				40			
8	41				42				43				44				45			
9	46				47				48				49				50			
10	51				52				53				54				55			
11	56				57				58				59				60			
12	61				62				63				64				65			
13	66				67				68				69				70			
14	71				72				73				74				75			
15	76				77				78				79				80			

Note. Since two squads completed their first trial without ever using the squad radio, the first scheduled trial of each squads was rerun

after the completion of the originally scheduled 75 trials. Beginning with the sixth trial (the second scheduled trial of Squad 1), the SL and SMs of each squad were reminded of the requirement that they were to use the squad radio in accordance with the operative TTP condition. The first scheduled trial for each squad was redefined as a practice trial (p) and the remaining 15 trials for each squad were defined as the experimental trials.

Table A-4. Order of Experimental Conditions Within and Across Squads in Phase 2 (adapted from Redden & Blackwell, 2001)

Platoon 1 -- Week 1									
Daylight					**Night**				
Trial	**Squad**	**Radio**	**Vignette**	**Script**	**Trial**	**Squad**	**Radio**	**Vignette**	**Script**
1	1	Y	A	1	19	1	N	D	1
2	2	Y	B	3	20	2	N	E	2
3	3	Y	C	2	21	3	N	F	1
4	1	Y	B	3	22	1	N	E	2
5	2	Y	C	2	23	2	N	F	1
6	3	Y	A	4	24	3	N	D	2
7	1	Y	C	2	25	1	N	F	1
8	2	Y	A	4	26	2	N	D	2
9	3	Y	B	1	27	3	N	E	1
10	1	N	A	4	28	1	Y	D	2
11	2	N	B	1	29	2	Y	E	1
12	3	N	C	4	30	3	Y	F	2
13	1	N	B	1	31	1	Y	E	1
14	2	N	C	4	32	2	Y	F	2
15	3	N	A	1	33	3	Y	D	1

16	1	N	C	4	34	1	Y	F	2
17	2	N	A	1	35	2	Y	D	1
18	3	N	B	3	36	3	Y	E	2

Table A-4. (continued)

Platoon 2 -- Week 2									
Daylight					Night				
Trial	Squad	Radio	Vignette	Script	Trial	Squad	Radio	Vignette	Script
1	1	N	B	1	19*	1	Y	E	1
2	2	N	C	4	20*	2	Y	F	2
3	3	N	A	4	21*	2	Y	D	2
4	1	N	C	4	22*	2	Y	F	2
5	2	N	A	1	23*	2	Y	D	1
6	3	N	B	1	24*	3	Y	E	1
7	1	N	A	1	25*	2	Y	D	1
8	2	N	B	3	26*	2	Y	E	2
9	3	N	C	4	27*	2	Y	F	2
10	1	Y	B	3	28	2	Y	E	2
11	2	Y	C	2	29	2	Y	F	1
12	3	Y	A	1	30	3	N	D	1
13	1	Y	C	2	31	3	N	F	1
14	2	Y	A	4	32	3	N	D	2
15	3	Y	B	3	33	3	Y	E	2
16	1	Y	A	4	**				
17	2	Y	B	1	**				
18	3	Y	C	2	**				

* Data were not used from these trials

** Data were not collected for these trials

Table A-4. (continued)

Platoon 3 -- Week 3									
Daylight					Night				
Trial	Squad	Radio	Vignette	Script	Trial	Squad	Radio	Vignette	Script
1	1	Y	C	2	19	1	N	F	1
2	2	N	A	1	20	2	Y	D	1
3	3	Y	B	1	21	3	N	E	1
4	1	Y	A	4	22	1	N	D	2
5	2	N	B	3	23	2	Y	E	2
6	3	Y	C	4	24	3	N	F	2
7	1	Y	B	1	25	1	N	E	1
8	2	N	C	2	26	2	Y	F	1
9	3	Y	A	1	27	3	N	D	1
10	1	N	C	4	28	1	Y	F	2
11	2	Y	A	4	29	2	N	D	2
12	3	N	B	3	30	3	Y	E	2
13	1	N	A	1	31	1	Y	D	1
14	2	Y	B	1	32	2	N	E	1
15	3	N	C	2	33	3	Y	F	1
16	1	N	B	3	34	1	Y	E	2
17	2	Y	C	4	35	2	N	F	2
18	3	N	A	4	36	3	Y	D	2

Table A-5. Sample SA Knowledge Test (Vignette-Script Number A-1, adapted from Redden, & Blackwell, 2001)

NAME: _____ RANK: _____ YRS IN ARMY: ____

UNIT: _____ DATE: _____

Please answer the following questions based on your experience with the system. Answer all questions as accurately as possible. Circle the appropriate letter.

6. How long will it take the OpFor to reinforce their units currently in McKenna?
   a. Less than 1 hour
   b. 1-2 hours
   c. 2-3 hours
   d. No reinforcements available
   e. Don't know

7. What type of reinforcements does the OpFor have?
   a. Motorized Infantry
   b. Air Assault Infantry
   c. Irregulars
   d. None
   e. Don't know

8. What was the location of the HIP Helicopter when 1st reported?
   a. 15K north of McKenna
   b. 5K north of McKenna
   c. 5K east of McKenna
   d. 15K east of McKenna
   e. Don't know

9. What is the latest reported disposition of the HIP Helicopter?
   a. Flying south 5K east of McKenna
   b. Landed east end of McKenna Airstrip debarking troops
   c. Landed east end of Kings Pond
   d. Shot down by AC-130
   e. Don't know

10. How many KIA/WIA did A Company receive from the marksman in the steeple?
   a. 2 KIA, 2 WIA
   b. 1 KIA, 1 WIA
   c. 0 KIA, 2 WIA
   d. 2 KIA, 0 WIA
   e. Don't Know

11. Where were the OpFor located in C4?
   a. Window 2-1 & 2-2
   b. Window 2-6 & 2-7
   c. Window 2-2 & 2-7
   d. None reported
   e. Don't know

Table A-5. (Continued)

1. How many ExFor KIA/WIA, if any, does 3rd Squad have at this time?
   a. 0 KIA, 2 WIA
   b. 1 KIA, 1 WIA
   c. 2 KIA, 0 WIA
   d. None reported
   e. Don't Know
2. Where, if any, were the COBs seen/reported?
   a. In C3
   b. Running from C3 to C4
   c. In B1
   d. None seen/reported
   e. Don't know
3. What items, if any, of intelligence value were found, on your objective?
   a. Map with ExFor positions
   b. Map with OpFor positions
   c. Roster of OpFor personnel
   d. Nothing found
   e. Don't know
4. Where is the platoon leader located?
   a. Enroute to your location
   b. With 1st Squad
   c. With 2nd Squad
   d. At Company CP
   e. Don't know
5. What is the status of the SAW's in 2nd platoon?
   a. 1 SAW Inop
   b. Both SAW's Inop
   c. No reported change to SAW status
   d. SAW's can not engage at this time
   e. Don't know

Table A-6. Squad Soldier Ratings of Critical Information Requirements (adapted from Redden & Blackwell, 2001)

SCALE
1 - Extremely unnecessary for performance
2 - Very unnecessary for performance
3 - Unnecessary for performance
4 – Neutral
5 - Necessary for performance
6 - Very necessary for performance

VIGNETTE QUESTION	MEAN	SAMPLE SIZE	QUESTION
A3-Q10	6.00	31	Any reports of OpFor using booby traps in McKenna?
A2-Q08	6.00	37	What is your squad's 5.56mm (ball) ammo status?
A1-Q06	5.82	38	Where were the OpFor located in C4?
A5-Q03	5.80	41	If used, where were the booby traps found?
A5-Q08	5.78	41	Any OpFor in C4; if so, how many/what size unit?
A4-Q08	5.77	39	How many OpFor were seen/reported in C4?
A2-Q06	5.75	36	Three OpFor escaped from C3, where did they go?
A4-Q03	5.64	39	Any reports of OpFor using booby traps?
A5-Q06	5.59	41	What direction is OpFor moving (vicinity of cemetery)?
A2-Q03	5.49	37	Any reports of OpFor using NBC?
A4-Q01	5.41	39	Most likely source of NBC attack?
A4-Q11	5.34	38	Where is the OpFor NBC lab located?
A4-Q10	5.33	39	Anything of intelligence value found?
A3-Q01	5.32	31	Current location of Platoon CCP/POW?
A1-Q01	5.29	38	OpFor reinforcement time?
A2-Q05	5.27	37	If reported, what are/were OpFor doing?
A1-Q09	5.26	38	What items of intelligence value were found?

Note 1. In the Vignette Question column, the letter represents the vignette and the number represents the script, e.g., A1 is Vignette A Script 1.

Note 2. Information required to correctly answer Items A1-Q01 and A1-Q06 was contained in scripted messages provided by the PL to the SL (Platoon Leader Radio Transmissions 11 and 7, respectively, as shown in Table A-1). Information required to correctly answer Question A1-Q09 was available only from observations made directly by members of the squad. As described in the text, for each squad taking this test in Phase 1, the mean percentage of squad members (including the SL) correctly answering Items A1-Q01 and A1-Q06 defined the estimated top-down SA score, and the percentage of squad members correctly answering Item A1-Q09 defined the bottom-up SA score.

Table A-7. Platoon/Squad Radio Transmission Log

Trial _____ Squad _____ Date _____ Start _____ Stop _____ Duration _____		
TTP _____ Vignette _____ Script _____ Radio _____ Channel _____ Rater _____		
Message Category	Duty Position	
	SL	PL / SM
Provide Acknowledgment		
Provide Direction		
Provide Information (Friendly)		
Provide Information (Threat)		
Provide Opinion		
Request Acknowledgment		
Request Direction		
Request Information (Friendly)		
Request Information (Threat)		
Request Opinion		
Unrelated to Mission		
Administrative/Other		
Inaudible		
Break Squelch		
Hot Microphone (Duration)		

Table A-8. Example Check Sheet for scoring SL Retransmission of Message Elements Provided by the PL

Vignette A--Script 1

Trial _____
Squad _____
TTP _____

___ Plt. CP in Bldg. C1
___ West end

___ 2 motorized vehicles reported
___ vicinity of Pinetree and Hourglass roads

___ HIP helicopter reported
___ 5K East of McKenna
___ moving SW

___ Co. CCP located at Plt. CCP/POW

___ A Co. under fire
___ from church steeple
___ 1 KIA, 1 WIA

___ Support Sqd. Engages OPFOR
___ in steeple

_*_ 3 OPFOR seen
_*_ in Bldg. C4
_*_ in Windows 2-6 & 2-7

___ Doctor believed to be in Bldg C4

___ OPFOR seen in Bldg. C2
___ NE window

___ 2 COBs running
___ from Bldg. C3
___ to Bldg. C4

_*_ HIP landed
_*_ East end of
McKenna Airstrip
_*_ debarking troops

___ 3rd Sqd. has 2 WIA
___ due to booby traps

___ PL has moved
to Bldg C3
___ to evacuate casualties

___ A Co. reports doctor seen
___ in Bldg. B1

___ Motorized vehicles turning
___ East on Hourglass road

Note. The three items marked with asterisks in Column 1 are essential message elements for Question 6 and the three items marked with asterisks in Column 2 are essential message elements for Question 1 in the Phase 1 SA Knowledge Test given in Appendix A-5.