Field Investigation of Radio Network Usage at the Dismounted Infantry Section Level

John Frim	*Barb Adams*	*Dave Tack*	*Michael Thomson*	*Linda Bossi*
Defence R&D Canada – Toronto, 1133 Sheppard Ave W, Toronto, ON, Canada M3M 3B9	Human Systems Inc, 111 Farquhar St, Guelph, ON, Canada N1H 3N4	Human Systems Inc, 111 Farquhar St, Guelph, ON, Canada N1H 3N4	Human Systems Inc, 111 Farquhar St, Guelph, ON, Canada N1H 3N4	Defence R&D Canada – Toronto, 1133 Sheppard Ave W, Toronto, ON, Canada M3M 3B9
John.Frim@drdc-rddc.gc.ca	badams@humansys.com	dtack@humansys.com	mthomson@humansys.com	Linda.bossi@drdc-rddc.gc.ca

Abstract

The Soldier Information Requirements Technology Demonstration (SIREQ TD) project is an experimentation program to identify technologies that significantly enhance the performance of our future soldiers. One of the study series involved a 2 x 2 factorial comparison of the benefits of digital maps over paper maps, and the use of radios vs. no radios. Thirty-two Canadian regular force infantry soldiers performed force-on-force tactical assault missions in wooded terrain, with each soldier participating in all four test conditions. The radios were configured to operate in 4 subnets: 1 channel for each of the 2 Assault Groups (4 soldiers on a channel); a Section Commander/2IC channel; and an all-users channel. Note that in the no-radio conditions soldiers still operated the press-to-talk switch to allow recording of communications, but the speaker volume was set to zero. All communications were date/time stamped, identified as to the user and channel, and the audio was digitally recorded for later analysis as to the nature and content of the message. The study showed that although the type and function of communication did not change dramatically across the four test conditions, there was an increased amount of overall communication when soldiers carried radios compared to when they did not. Other quantitative results pertaining to communications, situation awareness, perceived workload, and team effectiveness are presented, along with subjective measures collected by questionnaires and focus group discussions.

1 Introduction

Many nations around the world are embarking on soldier modernization programs of varying complexity. While some are seeking to improve basic clothing and equipment items, many are going down the path of "digitizing" their soldiers – essentially giving them computer technology that will allow them to "connect" to their comrades, their chain of command, perhaps remote weapons platforms, and possibly even the entire digital battle space. The capability to collect, send, receive, display, and act on information virtually instantaneously is the essence of Network Centric Warfare.

Defence R&D Canada has been supporting Canada's soldier modernization effort with a research and development project known as the Soldier Information Requirements Technology Demonstration (SIREQ-TD) project. The aim of SIREQ-TD is to define and empirically validate the performance requirements for the future Soldier System by demonstrating capability enhancements in command execution, target acquisition and situation awareness for the individual Canadian dismounted soldier in 2010-2015.

A detailed cognitive task analysis suggested that radio communications and digital map displays were two key areas of soldier information exchange that could benefit substantially from technology insertion. In fact, the cognitive task analysis identified the capabilities to transfer information and to communicate between members in a dismounted infantry section as critical requirements for mission success. Accordingly, intra-section communications and the exchange of situation awareness information became key focus areas of the SIREQ_TD project.

Early SIREQ-TD laboratory studies of radio communications showed that over 50% of the radio traffic at the small unit level was related to information regarding the location of friendly elements. It was postulated that if a digital

map were used to provide situation awareness, there may be an impact on the frequency and content of radio communications. This paper presents a few of the results of a study investigating the interaction of digital vs. paper maps with radio/no-radio communications conditions in field tactical assault missions in wooded terrain. The study was a follow-on to a similar study[1] conducted in the laboratory in a First Person Gaming environment.

2 Methods

2.1 Overview

A nineteen-day field trial was undertaken in a wooded area in Ft. Benning, Georgia, over the periods 29 October – 14 November, 2002 and 2 – 3 March, 2003. Thirty-two regular force Canadian infantry soldiers each performed eight force-on-force tactical assault missions in wooded terrain (two repeats of four experimental test conditions).

For any one mission, eight soldier participants worked together as an organic infantry section comprising two Assault Groups (AGs) that engaged an enemy force of four soldiers occupying a defensive position in the wooded area. AGs were led by the Section Commander (SC) and his Second-In-Command (2IC). Soldiers used C7A1 personal weapons (firing blank rounds) coupled to a SIMLAS laser target engagement system to simulate live weapons effects and record engagements. Enemy forces were dressed in opposing force dress and were armed with the same weapon system. All enemy force members followed a strict engagement script and rules of engagement. The four enemy force soldiers were not considered participants in the experiment. Human factors (HF) measures included communication measures, status awareness, workload, and teamwork factors. Subjective data were collected via questionnaires and focus groups administered at the end of each mission, as well as at the end of the entire study.

2.2 Equipment

2.2.1 Communications network

Soldiers used a Kenwood TK-280 radio with multiple scanning features that allowed users to scan other networks while sending on a specific network. Four networks were defined on the system as follows:

Network #1 = SC and 2IC only
Network #2 = AG 1 members only (i.e., four participants)
Network #3 = AG 2 members only (i.e., four participants)
Network #4 = All section members (i.e., all eight participants)

To talk to other members of a network, a participant selected the desired network, depressed the press-to-talk (PTT) button and spoke into the boom microphone integrated into the helmet. A computer-controlled digital recording system tracked and logged all voice radio communications during each mission. The server logged the time, sender identification, and network (thereby identifying the listeners), and stored a digital record of the communication in a WAV file for post-study semantic analysis. The communications system is depicted graphically in Figure 1 below.

2.2.2 Digital map display

The digital map display components are shown in Figure 2. The system comprised a Garmin Global Positioning System (GPS), a wrist-mounted display, and a finger mouse, all coupled to a Xybernaut MA-V wearable computer that was ultimately connected to a data radio. Soldier position was determined by the GPS and sent to a Mobile Instrumented Vehicle (MIV). Position data from all participants was integrated into a common picture and relayed back to all soldiers for display as soldier icons on a map or aerial photograph display of the region where the relevant mission was being conducted. The maps showed topography information as well as real-time display of one's own position and that of other section members.

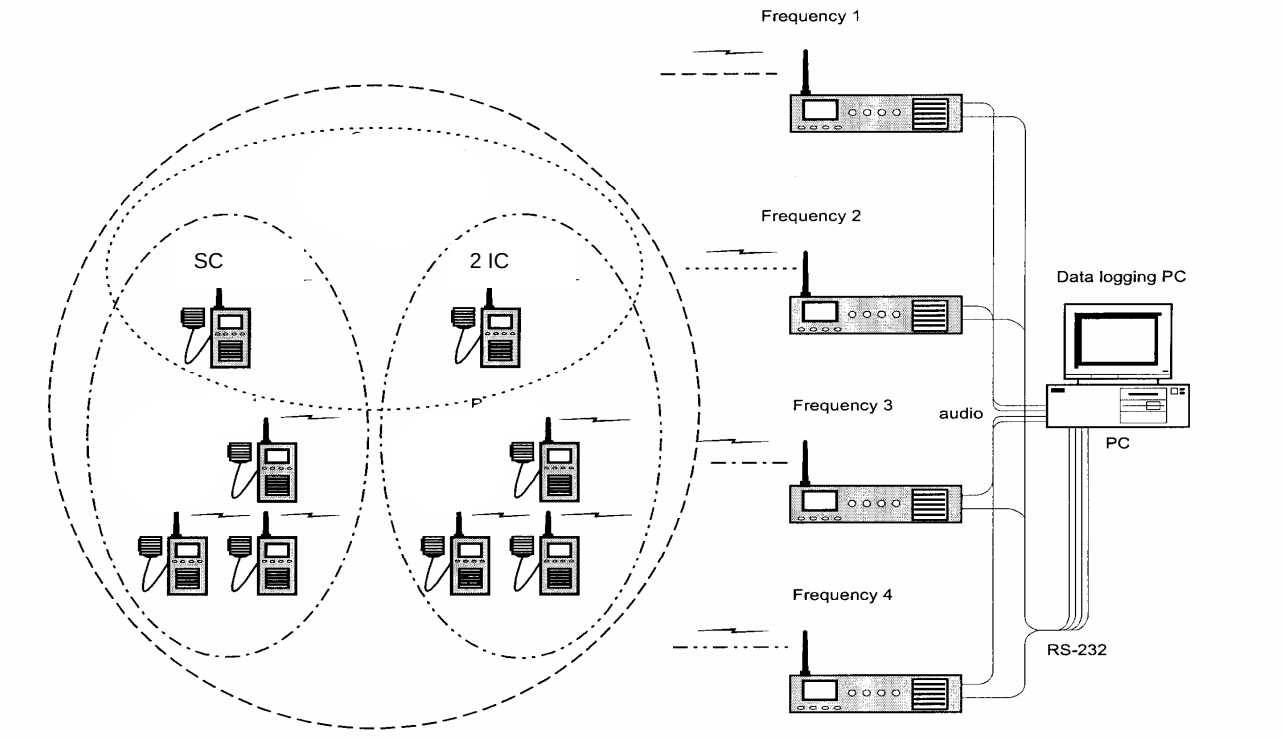

Figure 1: Communications Network

Figure 2: The components of the digital map display system

2.3 Experimental conditions

Two map and two radio test conditions were crossed in a 2x2 factorial experimental design as shown in Table 1. Each condition was exercised twice by each of four sections of soldiers, for a total of eight missions per test condition.

Table 1: Experimental Conditions

	No-Radio	Radio
PAPER MAP	✓	✓
DIGITAL MAP	✓	✓

To evaluate the effects of providing a digital map display of friendly force positions, a paper map option (i.e., the current in-service method) and a digital map option were compared.

a) Paper Map Conditions: The paper map conditions included a standard map with terrain representation to reflect the current in-service method.
b) Digital Map Conditions: The Xybernaut wearable computer with digital tablet displayed the real-time locations of each section member overlaid on a map of the wooded area.

To evaluate the effects of providing intra-section voice communications, two communications options were assessed: a no-radio option (i.e., the current in-service method) and the radio communications Local Area Network (LAN) configured with four subnets as described above.

a) No-Radio Conditions: Participants employed current standard in-service communications methods; i.e., soldiers used hand-signals, and spoke or yelled voice commands and replies depending on the requirements of the situation. To permit analyses of the frequency, nature and content of the communication, participants were required to depress their PTT button during each voice exchange so that the radio recording system could log the communication; however, the radio speaker volume was turned off so that no communication could actually be heard over the radio network. In the case of hand-signals, participants were instructed to depress their PTT and quietly "verbalize" the hand-signal instruction. The radio networks were monitored by experimenters to ensure that only communication "logging" rather than radio interaction was occurring.
b) Radio Conditions: All four radio communication system subnets were utilized to provide the participants with a range of communication network options. Prior to the start of the experiment, participants were assigned membership to the appropriate radio network. Since the SC and the 2IC each led one of the two AGs, they had access to three possible networks (All Section Net, SC/2IC Net, and AG Net) while the remaining riflemen had access to two networks (their AG Net and the larger All Section Net).

2.4 Missions

The missions executed in this experiment provided goal-oriented team-based scenarios that were contextually relevant to small unit infantry operations. They exploited small unit tactics to emphasize issues of control within the section and within each AG, stealth during the approach, and coordination between AGs during the assault. Each mission was carefully configured to standardize the experimental mission parameters between conditions, within the context of tactics for wooded operations. The general approach and specific phases for each mission are outlined below.

2.4.1 General briefing

All participants were briefed on the goals and protocol of the experiment, the general mission structures, and the radio and map test conditions. Following this they were instructed in the use, installation, and operation of their SIMLAS equipment and given the opportunity to practice head-to-head target engagements. Participants were also trained on the use of the radios and digital map displays and given an opportunity to operate and gain experience with the devices, including interaction with other members of their section.

2.4.2 Experimental execution

Following the general briefing and training sessions, missions were carried out in four phases as described below. Soldiers executed up to 6 missions each day.

Phase 1: Mission Briefing (10 min): Prior to each mission, the Lead Experimenter briefed the section and provided them with execution orders, rules of engagement, a defined route and entry point for each AG, and limited information about the enemy at the objective. Participants were reminded of the communications/map experimental condition being tested.

Phase 2: Mission Planning (15 min): The section was given an opportunity to study the map of the wooded area. Each SC or 2IC leader then provided guidance or instructions to his AG as required.

Phase 3: Mission Execution (30 min): Once started, the mission continued until the objective was reached or 30 minutes had elapsed. Each AG moved tactically with stealth along its assigned approach route. One AG was engaged enroute by enemy forces. This surprise engagement forced a delay and required the AG to coordinate team movement to avoid or dispatch the enemy forces. This delay affected the coordination and awareness of the two AGs. At this point, the experiment controller paused the mission to allow for the collection of situation awareness data. Following the mission freeze and data collection, the two AGs maneuvered to their objective and began a coordinated assault.

Phase 4: Post-Mission Measurements (15 min): Following each mission, participants completed a post-mission questionnaire. Individual participant comments were recorded and expanded through interview techniques. A final focus group discussion was held at the completion of all missions.

2.5 Enemy

Enemy soldiers were used as a means of delaying and obstructing the AGs. Placing enemy in key locations required the two AGs to use communication to coordinate their movements and their fire.

2.6 Casualty control

For this experiment there was no casualty control. Enemy soldiers were able to shoot at, hit and kill AG soldiers with the SIMLAS laser target system. AG members killed before the status awareness freeze were instructed to lie on the ground until after the mission freeze when they were "regenerated". Any AG casualties after the freeze were not regenerated.

2.7 Dependent measures

A variety of data were collected before, during, and after each mission, as well as at the start and end of the experiment.

2.7.1 During the mission freeze

The following status awareness information was collected during the mission freeze:

a) Awareness of casualties in other AG: The number of casualties (0 to 4).
b) Awareness of RV timing: The time that soldiers believed they would arrive at the RV using a 4-point scale ranging from very early to very delayed.
c) Prediction of mission completion: The time that soldiers believed they would complete the mission (5-point scale ranging from very early to very delayed), final section casualties (8-point scale ranging from 0 to 8), and likelihood of mission success (4-point scale ranging from very unlikely to very likely).

2.7.2 Throughout each mission

All communications under all conditions were captured using the computerized voice communications recording system. A post-hoc semantic analysis of the content of each voice message was used to classify the communication according to the following criteria (adapted from Entin[2]):

a) Type: Messages were first type-classified as a "Transfer" of information, a "Request" for information, an "Order" to perform some task, an "Acknowledgement" of receipt of any of the three previous types, an "Informal Order", "Getting Attention", or "Repeat Message". Other communications such as "Comms Check", "Prestle Stuck", "Requesting the Experimenter", "Keystroke", "Invalid File Type", or "Purely Social" communications were classified as "Other".
b) Function: Each message was then classified by its information transfer function. Functions describe the purpose for transferring the information. Functional classifications include "Status", "Location", "Task Assignment", and "Planning/Problem Solving".

c) Enemy / Friendly: For functions involving "Status" or "Location", the message was further classified as relating to "Enemy" or "Friendly" forces.
Message classification example: while in contact with an enemy sniper the AG leader may ask: "Fire Team Alpha, do you have a fix on the sniper location from your position?" This message would be classified as a "Request" for "Location" of "Enemy" information. The reply by Fire Team Alpha, "Sniper observed in 2nd story window of brown office building to my front", would be classified as a "Transfer" of "Location" of "Enemy" information. The SC response, "Fire Team Alpha, prepare to provide suppressive fire on my signal", would be classified as an "Order" for a "Task Assignment"; and so on.

d) Pathways: The four voice communications networks represented information transfer pathways between different roles and groupings within the section. Using the voice communications LAN software, each message was logged according to the networks described earlier.
e) Anticipation Ratios: The ability of team members to anticipate the information needs of other members is an indication of teamwork and coordination. Anticipation ratios provided some insight into this anticipation behaviour by relating the number of information transfers to the number of requests (i.e., if transfers exceed requests then anticipation behaviour exists).

2.7.3 End of each mission

The following data were collected at the end of each mission:

a) Teamwork Measures: Participants completed a Teamwork Questionnaire to assess the performance of each section for a variety of teamwork dimensions (e.g., team communication, anticipation of information needs, coordination, team orientation). Participants rated teamwork on a 7-point Likert scale where 1 represented "Strongly Disagree" and 7 represented "Strongly Agree".
b) Workload: Participants completed a NASA TLX Questionnaire indicating the levels of subjective workload experienced during the mission. Participants rated six measures of workload: mental demand, physical demand, temporal demand, task performance, effort, and frustration. Participants rated the workload on a scale where "Low" represented "easy/simple" and "High" represented "demanding/laborious".

2.7.4 End of the experiment

After completing all missions participants completed an Exit Questionnaire on acceptability ratings for the radio vs. no-radio and digital map vs. paper map conditions. They were also asked to rate how important the radio and digital map were throughout different stages of the mission. Finally, a focus group was held to discuss participants' opinions and experiences with the following issues:

- The benefits and drawbacks of having a digital map display of friendly forces;
- The benefits and drawbacks of having radio communications;
- Lessons learned about the use of a radio communications network for information transfer;
- The opportunities for exchanging information in different modalities (e.g., digital map vs. radio); and
- The implications of an information exchange network on small team tactics.

3 Results

3.1 Overview of communications

Table 2 presents the total number of WAV files, the total number of transmissions (discrete thoughts), and the mean number ± standard deviation of transmissions across missions for each of the conditions. (Note that the N of 8 represents 2 missions by each of 4 sections in each of the test conditions; note also that 1 additional mission was run in each of the digital map conditions).

Table 2: WAV files and transmissions

	N	# of WAV files	# of transmissions	Mean ± SD transmissions across missions
Paper/No-Radio	8	916	755	94 ± 54.4
Paper/Radio	8	1677	1600	200 ± 48.6
Digital/No-Radio	9	1088	885	98 ± 57.9
Digital/Radio	9	1765	1779	198 ± 103.7
Total	**34**	**5446**	**5019**	

Figure 3 shows the proportions of the total number of transmissions in the four conditions. In general, soldiers communicated approximately two times more often when they had a radio than when they did not.

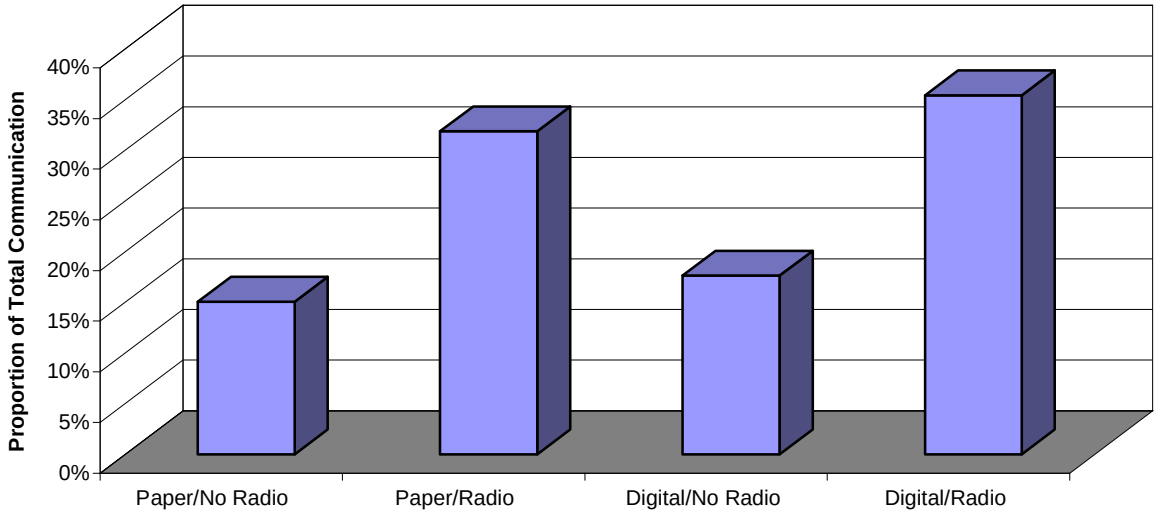

Figure 3: Percentage breakdown of total communication by condition

As Figure 3 shows, the Digital/Radio condition had 35% of all communication and the Paper/Radio condition had 32%, compared to 18% for the Digital/No Radio condition and 15% for the Paper/No Radio. Together, the radio conditions accounted for 67% of the total communication transmissions across the four test conditions.

3.2 Type of Communication

Figure 4 shows the raw frequencies of the various types of communication as a function of condition. The graph indicates that every type of communication was more frequent when radios were available compared to not having radios. Clearly, Transfers and Orders were the most dominant types of communication.

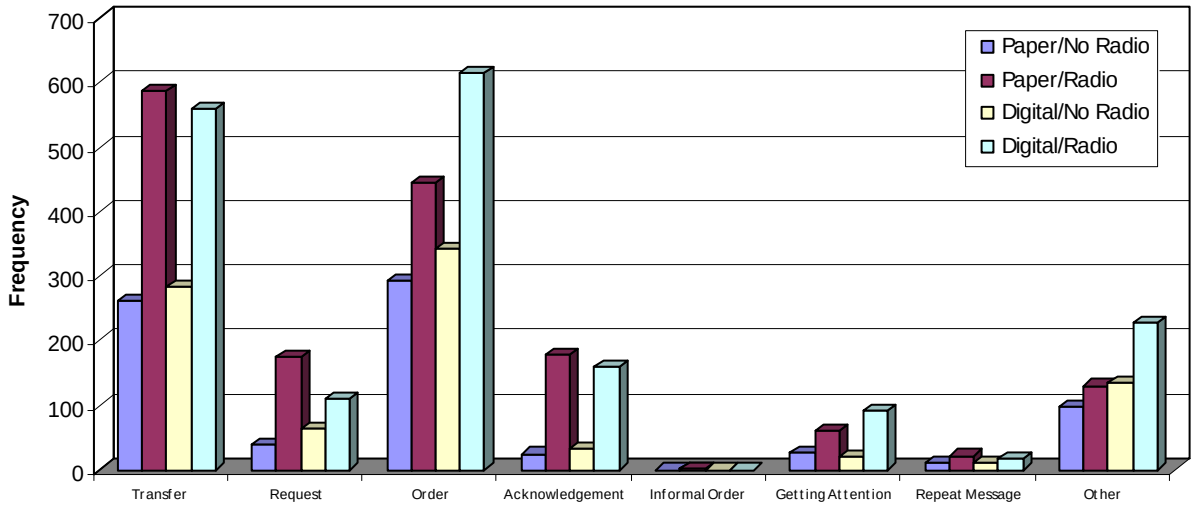

Figure 4: Frequency of type of communication by condition

Since the number of transmissions differed considerably between conditions, the type of communication was expressed as a percentage of all the communication within that condition, and these results are shown in Figure 5.

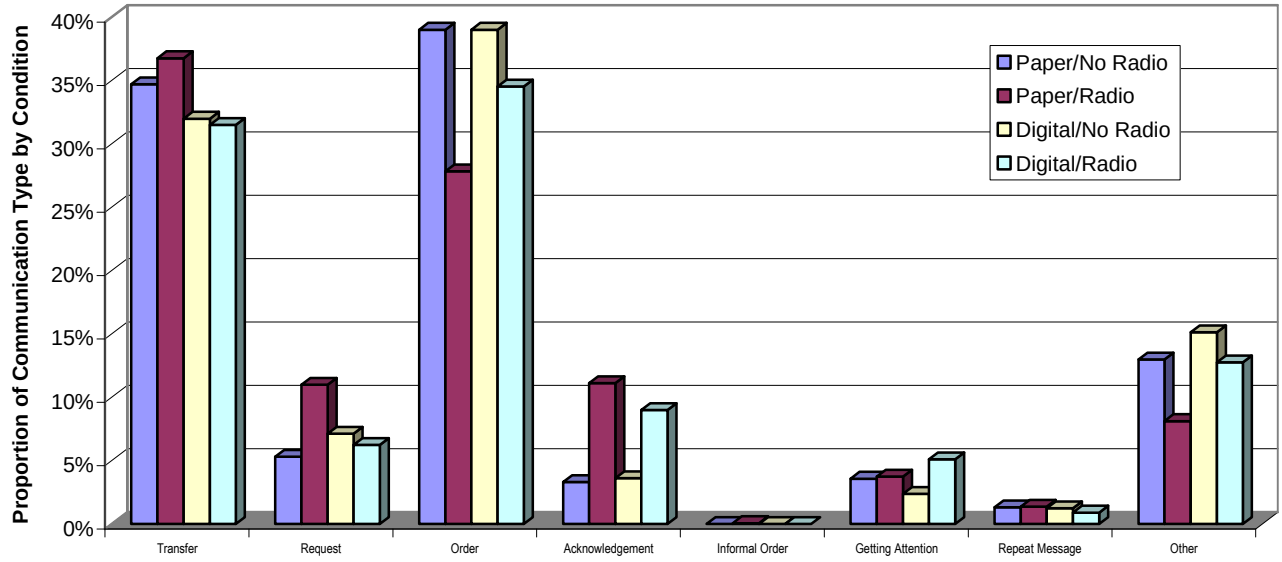

Figure 5: Percentage of type of communication by condition

While Transfers and Orders are still dominant, it is interesting to note the decrease in the percentage of Orders and the strong increase in the percentage of Acknowledgements given when radios were available (compared to the no-radio conditions). Also, having digital maps available resulted in a slight decrease in the percentage of communications devoted to Transfers of information, presumably because some of that information was presented on the digital map displays. The relatively high proportion of Requests for information during condition Paper/Radio supports the notion that soldiers want to have status information, it is not available on a paper map, but a radio makes it easy to request such information. Overall, the biggest differences in the types of communication were more the result of the introduction of a radio and not due to the provision of a digital map.

3.3 Function of Communication

Figure 6 shows the frequency of the functional natures of the communications by condition. When soldiers carry radios, they communicate their status and location far more frequently than when they do not have radios.

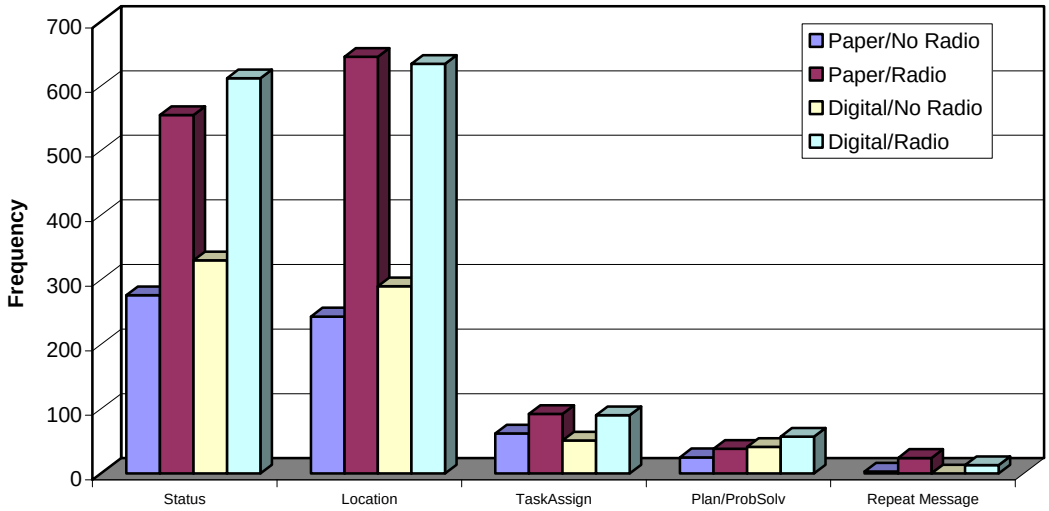

Figure 6: Frequency of function of communication by condition

Figure 7 presents the function data as a percentage of the total communication in each test condition. It illustrates that transmissions regarding location and status were the two most common function-related communications. There were only small differences between the four test conditions for Status and Location functional natures.

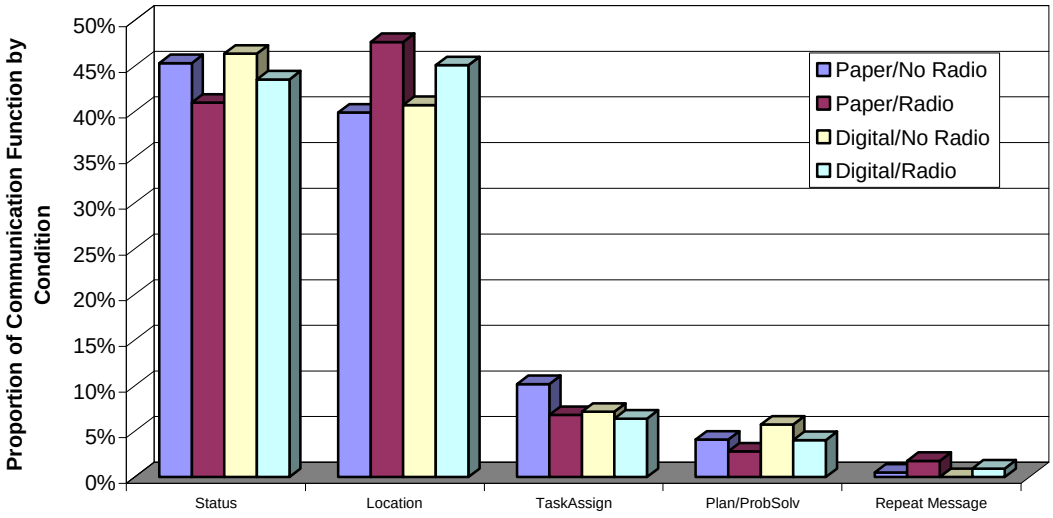

Figure 7: Percentage of function of communication by condition

3.4 Friendly/Enemy references

Figure 8 presents the proportion of friendly/enemy references across the four test conditions. As in previous studies, information about friendly forces is important to soldiers. In this study there were no differences between conditions as a function of maps or communications capability.

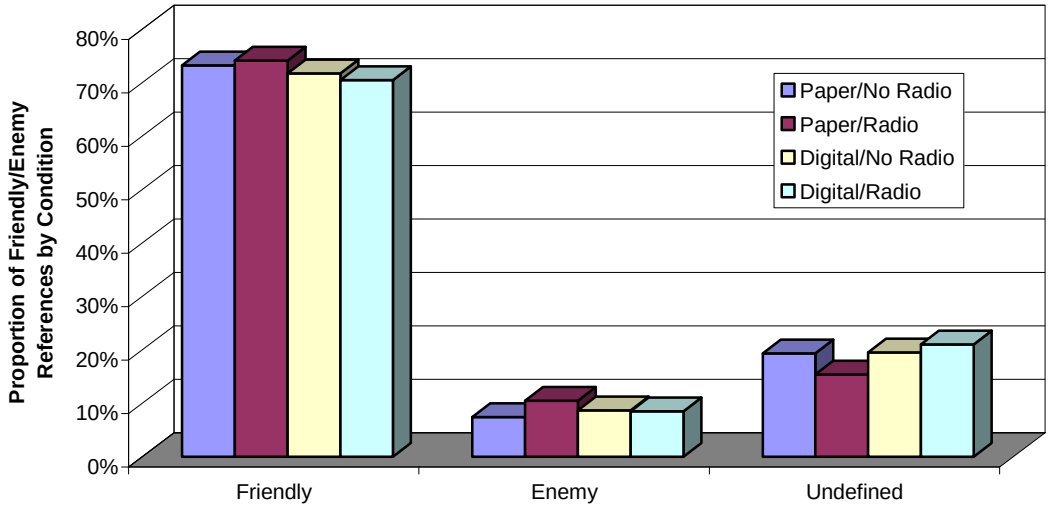

Figure 8: Friendly/enemy references by condition

3.5 Network usage/pathways of communication

The four different radio networks allowed soldiers in different roles to choose the network over which they would communicate with others. Table 3 shows the number of radio transmissions over each of the four networks.

Table 3: Transmissions by network

Network #	Composition (# speaking members)	# Transmissions
1	SC and 2IC (2)	246
2	SC's Assault Group (4)	1008
3	2IC's Assault Group (4)	550
4	All Section Members (8)	3215
Total		**5019**

Figure 9 shows the network usage as a percentage of all communications and indicates that the All Section Members net was the most frequently used radio network for communication. This finding was different than that found in Adams, Tack, and Sartori[1] where section members used the AG networks more often than the all members net and the private leaders net. This could be due to different test environments, and it might be more efficient to have all members connected when performing tactical assault missions in the field as opposed to working in a First Person Gaming laboratory environment.

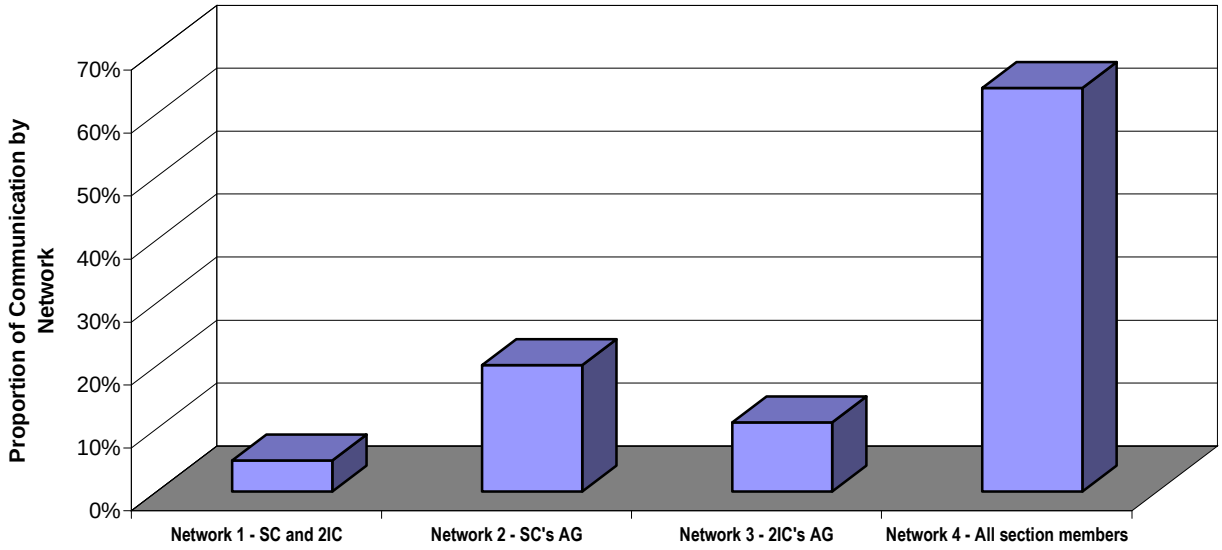

Figure 9: Proportion of radio communications by network

3.6 Anticipation ratios

In this study soldiers anticipated the information needs of other members of the section in all test conditions. In the Paper/No-Radio condition there was a fairly high anticipation ratio of 6.6 compared to the Paper/Radio condition of 3.3. For the Paper/No-Radio condition, the relatively high anticipation ratio may represent a procedural form of redundancy, perhaps representing an effort to compensate for perceived weaknesses with a digital map and radio. The digital map conditions showed only a small change in anticipation ratio when soldiers had a radio compared to when they did not.

3.7 Subjective measures

The subjective measures collected in this study were analyzed statistically and a brief summary of significant or interesting results is presented below.

3.7.1 Status awareness measures

Soldier rated their awareness of other casualties significantly higher in the paper map missions than in the digital map missions. There were no significant differences for awareness of RV timing or mission completion time between conditions.

3.7.2 Teamwork

Teamwork ratings were relatively high (5.2 to 5.5 on a scale of 1 to 7) across all conditions, but there were no significant differences between conditions.

3.7.3 Workload

In general, perceived workload was rated relatively low in all conditions (an average of about 6 out of 18), but soldiers did indicate significantly lower workload in missions with a digital map than in missions with a paper map. There were no other significant main effects or interactions.

3.8 Exit questionnaire results

At the end of the experiment participants completed the exit questionnaire and participated in a focus group. They were asked to comment specifically on the main study factors of communication with and without radios, and paper vs. digital maps. They were also asked to provide general feelings regarding radios and digital maps. The results are presented below.

3.8.1 Radio vs. no-radio

Information transfer: All 10 criteria related to information transfer showed statistically significant advantages of having radios vs. not having radios for communication.
Coordination and awareness within and between assault groups: All 9 criteria related to coordination and awareness showed statistically significant benefits of having radio communications.
Overall acceptance of radio vs. no-radio: Soldiers were overwhelmingly in favour of having radio communications.

3.8.2 Paper vs. digital map

Participants were asked to rate factors relating to location awareness (self, other members of their own AG, members of the other AG), coordination within the AG (coordination of AG movement, coordination of AG fire, coordination of AG action, issuing/receiving orders, designating targets, sharing information), and coordination between AGs (coordination of section movements, coordination of section fire, coordinate of section actions, sharing information, ability to maintain mission tempo, ability to meet mission timings, anticipating the action of the other AG). For all factors, the digital map was rated significantly better than the paper map.

3.8.3 General feelings regarding radios and digital maps

Participants were asked to compare the benefits of the two technologies in 13 areas related to mission capabilities; the radio was rated significantly more important than the digital map in 11 areas (awareness of the battle situation, coordination within the section, teamwork, issuing/receiving orders, passing information, requesting information, tempo of mission, ability to maintain stealth, ability to adapt to changes in mission, minimizing casualties, and overall mission success), with no significant difference in the remaining areas (awareness of friendly forces, achieving mission timings). The digital map was seen as more important that the radio for pre-mission briefing, but the radio was more of an asset during approach to the objective, assault on the objective, and consolidation after the mission.

4 Conclusions

Overall, when investigating the type and function of voice communication within a dismounted infantry section engaged in a wooded area assault with or without a radio and/or digital map, the results showed very little difference across the four test conditions. Furthermore, the findings in the current study reflect, to a large degree, similar findings in the previous studies[1, 3, 4]. For example, when soldiers carried radios, there were fewer orders than when they did not carry a radio. The introduction of a digital map did not appear to alter the kind of communication that soldiers used.

In both exit questionnaires and focus groups, participants were highly favourable about the provision of a digital map and radio communications. Radios were seen to significantly enhance information transfer and coordination within and between AGs. Digital maps were rated as significantly enhancing location awareness and coordination within and between AGs. However, in general, having a radio was seen as being more important than having a digital map for most mission capabilities, including being aware of the battle situation, coordinating with the section, adapting to unexpected changes, and for minimizing casualties. In fact, radios were rated very important for overall mission success, whereas digital maps were rated to be somewhat less important. Additional ratings focusing on the utility of digital maps and radio during mission phases showed that digital maps have the most utility during the pre-mission briefing phase, presumably for planning and to enable plotting out mission routes. However, radios were seen as more important than digital maps for approaching and assaulting the objective, as well as during the consolidation phase of a mission.

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This paper was first presented at the SPIE Defense and Security Symposium in Orlando, Florida, 17-21 April 2006, and published as manuscript 6249-26 in the conference proceedings.