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FIELD EVALUATION OF DIGITAL MAPS AND RADIO COMMUNICATION IN DISMOUNTED INFANTRY OPERATIONS

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Abstract

As part of the Soldier Information Requirements Technology Demonstration (SIREQ-TD) project, this study examined the impact of providing both digital mapping and radio communication to dismounted infantry teams performing tactical assault missions in a wooded environment.

A nineteen-day field trial was conducted in a wooded area in Ft. Benning, Georgia, over the periods 29 October – 14 November, 2002, and 2 March – 3 March, 2003. Thirty-two Canadian regular force infantry soldiers performed force-on-force tactical assault missions in wooded terrain. Each soldier participated in all four research conditions, which included a paper map and no radio (Paper/No Radio), a paper map and a radio (Paper/Radio), a digital map and no radio (Digital/No Radio), and a digital map and a radio (Digital/Radio). For any one mission, eight soldiers worked together as an organic infantry section, comprised of two Assault Groups (AGs), to engage an enemy force of four soldiers occupying a defensive position in the wooded area.

The study showed that although the type and function of communication did not change dramatically with and without a digital map and radio, there was an increased amount of overall communication when soldiers carried radios compared to when they did not. Results also showed that there were some differences in team processes. More specifically, participants felt they had a better awareness of casualties with a paper map than with a digital map. Participants did rate perceived workload significantly lower with a digital map, regardless of whether they had a radio or not, but there were no perceived differences in teamwork.

In both exit questionnaires and focus groups, participants were highly in favour of having a digital map and radio communications. Radios were seen to significantly enhance information transfer, as well as coordination within and between AGs. Digital maps were rated as significantly enhancing location awareness, as well as coordination within and between AGs. Both digital maps and radios were rated as significantly more acceptable than the current in-service alternatives. In general, however, 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 as 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 for being able to plot 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.

Limitations of the current study are discussed. The primary limitation relates to the serious technical difficulties encountered while conducting this study, as the digital mapping systems did not perform very well. As such, the true value of digital mapping may have been underestimated by participants. Implications for future research regarding the digital map are discussed.

Résume

Dans le cadre du Projet de démonstration technologique des besoins des soldats en matière d'information (SIREQ TD), la présente étude s'est intéressée aux répercussions qu'aurait le fait de doter les équipes d'infanterie débarquée effectuant des missions tactiques d'assaut en terrain boisé, à la fois d'une carte numérique et d'un système de radiocommunication.

Un essai en campagne de 19 jours a été mené en terrain boisé, à Ft. Benning, dans l'État de la Georgie, du 29 octobre au 14 novembre 2002 ainsi que les 2 et 3 mars 2003. À cette occasion, 32 soldats d'infanterie de la force canadienne régulière ont effectué des missions tactiques d'assaut de force contre force en terrain boisé. Chaque soldat a pris part aux quatre scénarios à l'étude suivants : carte imprimée, pas de radio (imprimée/pas de radio), carte imprimée et radio (imprimée/radio), carte numérique, pas de radio (numérique/pas de radio) et carte numérique et radio (numérique/radio). Lors de chacune des missions, huit soldats étaient regroupés en une section d'infanterie organique formée de deux groupes d'assaut chargés d'affronter une force ennemie composée de quatre soldats qui occupaient une position défensive, en terrain boisé.

L'étude a démontré que, bien que le type et que la fonction des échanges n'aient pas changé de manière significative, qu'une carte numérique et qu'une radio ait ou non été disponibles, on a noté que les échanges étaient plus nombreux, lorsque les soldats étaient dotés de radios, que lorsqu'ils n'en étaient pas. Les résultats ont aussi mis en évidence certaines différences sur le plan des processus de l'équipe. De manière plus particulière, les participants étaient d'avis qu'ils étaient plus conscients des pertes avec une carte imprimée qu'avec une carte numérique. Les participants ont estimé que la charge de travail perçue était considérablement moindre lorsqu'ils pouvaient s'appuyer sur une carte numérique, qu'ils aient ou non été dotés d'une radio, bien qu'ils n'aient pas relevé de différence sur le plan du travail d'équipe.

Tant à l'occasion de questionnaires administrés au terme de l'exercice que de groupes de discussion, les participants se sont montrés nettement en faveur de la solution de la carte numérique et du système de radiocommunication. On a estimé que les radios permettaient d'améliorer considérablement le transfert de l'information, ainsi que la coordination tant au sein des groupes d'assaut qu'entre ceux-ci. On a estimé que les cartes numériques permettaient d'améliorer considérablement la prise de conscience quant à la situation géographique, ainsi que la coordination tant au sein des groupes d'assaut qu'entre ceux-ci. Aussi bien les cartes numériques que les radios ont été jugées nettement plus acceptables que les solutions actuelles. De façon générale, on a cependant estimé que, pour la plupart des fonctions des missions, il était plus important d'avoir une radio qu'une carte numérique, y compris pour connaître la situation sur le champ de bataille, la coordination avec la section, l'adaptation aux changements imprévus ainsi que la réduction des pertes. En fait, les radios ont été jugées très importantes pour la réussite générale de la mission, alors que les cartes numériques s'avéraient un peu moins importantes. D'autres évaluations s'intéressant particulièrement à l'utilité des cartes numériques et des radios durant les phases des missions ont démontré que les cartes numériques étaient le plus utiles durant la phase de briefing préalable à la mission, vraisemblablement pour la planification et du fait qu'elles permettaient de tracer les itinéraires de la mission. On a toutefois jugé que les radios étaient plus utiles que les cartes numériques lorsqu'il s'agissait de s'approcher de l'objectif et de donner l'assaut, ainsi que durant la phase de consolidation de la mission.

On traite des limites de l'étude en cours. La principale limite concerne les graves difficultés techniques auxquelles on a été confronté dans le cadre de la présente étude, puisque les systèmes de cartographie numérique n'ont pas très bien fonctionné. En cela, il se peut que les participants aient sous-estimé la véritable utilité des systèmes de cartographie numérique. On traite des répercussions en matière de recherche future, relativement aux cartes numériques.

Executive Summary

This study is the fourth and final in a series exploring the impact of radio communication on small infantry teams for the Soldier Information Requirements Technology Demonstration (SIREQ-TD) project. The SIREQ cognitive task analyses identified the abilities to transfer information and to communicate between members in a dismounted infantry section as critical requirements for mission success. Most soldier modernization programs have adopted an intra-section radio as part of their hardware ensemble. Ongoing technological developments have also made the use of personal digital maps during missions possible. However, the implications of providing digital map technology as well as radio technology have yet to be tested empirically within a field setting.

The main purpose of this study was to determine the effects of a digital map and/or radio on intra-section communication and team performance and process, as well as to gather feedback about the relative merits of this equipment. An earlier laboratory study (Adams, Tack & Sartori, 2004b) found that although workload perceptions were unaffected by the presence of a digital map, participants' perceptions of workload decreased when they had radios, and perceptions of teamwork increased. However, within the laboratory setting, team performance measures showed no change with the addition of digital maps and radio communication. The following field study examined the impact of providing digital mapping and radio communication capabilities on dismounted infantry teams in a wooded environment.

In this investigation, the following aims were pursued:

- To investigate the types, functions, and pathways of communications within a dismounted infantry section, with and without digital maps and radios.
- To determine differences in communication concerning location in missions with/without a map.
- To explore how digital maps and radios compare to paper maps and no radios, in terms of team process and performance. [1]
- To gather feedback from soldiers regarding the advantages and disadvantages of a digital vs. paper map, in combination with radios (and without radio) with respect to hardware and perceived impact on team process and performance

A nineteen-day field trial was conducted in a wooded area in Ft. Benning, Georgia, over the periods 29 October – 14 November, 2002, and 2 March – 3 March, 2003. Thirty-two Canadian regular force infantry soldiers performed force-on-force tactical assault missions in wooded terrain. Each soldier participated in all four conditions, which included Paper Map/No Radio, Paper/Radio, Digital Map/No Radio, and Digital Map/Radio. For any one mission, eight soldiers worked together as an organic infantry section, comprised of two Assault Groups (AGs), to engage an enemy force of four soldiers occupying a defensive position in the wooded area.

Researchers categorized communications in all conditions according to type (e.g. orders, transfers, etc.) and function (e.g. status, location, etc.), and further classified them as relating to enemy or

[1] Although we had hoped to assess team performance, this could not be assessed due to the failure of the SIMLAS system to record data reliably.

friendly forces. Team processes (with a digital map and radio and without a digital map and radio) such as status awareness, teamwork, and workload were also examined. Exit questionnaires and a focus group allowed discussion about the relative merits of these new capabilities.

The study showed that although the type and function of communication did not change dramatically with and without a digital map and radio, participants used voice communication approximately two times more often when they had a radio than when they did not. There was a large difference in the frequency of communications relating to status and location in the radio conditions compared to the no radio conditions. With respect to team processes, participants felt they had a better awareness of casualties with a paper map than with a digital map. Participants did rate perceived workload significantly lower with a digital map, regardless of whether they had a radio or not, but there were no perceived differences in teamwork.

In both exit questionnaires and focus groups, participants were highly in favour of the provision of a digital map and radio communications. Radios were seen to significantly enhance information transfer, as well as coordination within and between AGs. Digital maps were rated as significantly enhancing location awareness, as well as coordination within and between AGs. In general, however, 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 as 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 for being able to plot 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.

It is important to note, however, that this study has a potentially serious limitation stemming from the technical difficulties encountered while conducting this study. In specific, the digital mapping systems did not perform very well, so the fact that participants seemed to favour having radio over digital mapping capabilities may be a direct result of the poor functioning of the specific systems used in this study and less a true test of what this capability might contribute to infantry operations. As such, the results of this study need to be replicated in order to understand the true value of digital mapping.

Sommaire

La présente étude est la quatrième et dernière d'une série qui porte sur les répercussions des communications radio sur les petites équipes d'infanterie, dans le cadre du Projet de démonstration technologique des besoins des soldats en matière d'information (SIREQ TD). Les analyses de tâches cognitives du SIREQ ont révélé que les capacités en matière de transfert d'information et d'échange entre les membres d'une section d'infanterie débarquée revêtaient une importance critique pour assurer la réussite de la mission. La plupart des programmes de modernisation de l'infanterie incluent, dans le matériel de base, un système de radiocommunication intra-section. Les progrès technologiques continuels ont également fait en sorte qu'il est désormais possible de faire appel, durant les missions, à des systèmes de cartographie numérique personnels. Cependant, les répercussions de la possibilité d'avoir recours tant à des systèmes de cartographie numérique qu'à des systèmes de radiocommunication n'ont pas encore été testées de manière empirique, sur le terrain.

Le principal objectif de cette étude était de déterminer les répercussions du recours à un système de cartographie numérique et/ou à un système de radiocommunication sur les échanges intra-section, sur le rendement de l'équipe ainsi que sur les processus de celle-ci, en plus de recueillir des commentaires sur les mérites relatifs de cet équipement. Dans une étude en laboratoire antérieure (Adams, Tack et Sartori, 2004b), on est venu à la conclusion que, bien que la présence d'un système de cartographie numérique n'ait pas eu de répercussions sur les perceptions de la charge de travail, la perception des participants quant à cette dernière s'en trouvait réduite lorsqu'ils avaient à leur disposition des radios, tandis que les perceptions du travail d'équipe s'en trouvaient augmentées. Toutefois, dans le cadre des tests en laboratoire, les mesures du rendement de l'équipe ont démontré que l'ajout de systèmes de cartographie numérique et de radiocommunication n'avait rien changé. L'étude sur le terrain suivante s'est intéressée aux répercussions de la possibilité, pour des équipes d'infanterie débarquée, œuvrant en terrain boisé, de se servir de systèmes de cartographie numérique et de radiocommunication.

Dans le cadre de la présente enquête, nos objectifs étaient les suivants :

- Examiner les types, les fonctions ainsi que les modes de communication au sein d'une section d'infanterie débarquée, avec ou sans système de cartographie numérique et radio.
- Déterminer les différences sur le plan des échanges en ce qui concerne l'emplacement lors de missions, avec ou sans carte.
- Examiner dans quelle mesure la solution prévoyant le recours à un système de cartographie numérique et à une radio se compare à celle qui prévoit le recours à une carte imprimée, sans radio, sur le plan des processus et du rendement de l'équipe[2].
- Recueillir des commentaires des soldats, pour ce qui est des avantages et des inconvénients des cartes numériques par rapport aux cartes imprimées, utilisées conjointement avec les radios (ou sans celles-ci) sur le plan du matériel et des répercussions perçues sur le rendement et les processus de l'équipe.

[2] Bien que nous espérions pouvoir évaluer le rendement de l'équipe, cela s'est avéré impossible, du fait que le système SIMLAS n'a pas été en mesure de consigner les données de manière fiable.

Un essai en campagne de 19 jours a été mené en terrain boisé, à Ft. Benning, dans l'État de la Georgie, du 29 octobre au 14 novembre 2002 ainsi que les 2 et 3 mars 2003. À cette occasion, 32 fantassins de la force canadienne régulière ont effectué des missions tactiques d'assaut de force contre force en terrain boisé. Chaque soldat a pris part aux quatre scénarios à l'étude suivants : carte imprimée, pas de radio (imprimée/pas de radio), carte imprimée et radio (imprimée/radio), carte numérique, pas de radio (numérique/pas de radio) et carte numérique et radio (numérique/radio). Lors de chacune des missions, huit soldats étaient regroupés en une section d'infanterie organique formée de deux groupes d'assaut chargés d'affronter une force ennemie composée de quatre soldats qui occupaient une position défensive, en terrain boisé.

Les chercheurs ont regroupé les échanges dans toutes les conditions, par rapport à leur type (c.-à-d. ordres, transferts, etc.) et leur fonction (c.-à-d. état, emplacement, etc.) avant de préciser encore s'ils concernaient les forces ennemies ou amies. On s'est également intéressé aux processus de l'équipe (avec carte numérique et radio et sans carte numérique et radio) comme au chapitre de la prise de conscience quant à la situation, au travail d'équipe et à la charge de travail. Des questionnaires administrés au terme de l'exercice et un groupe de discussion ont permis d'échanger sur les mérites relatifs de ces nouvelles capacités.

L'étude a démontré que, bien que le type et que la fonction des échanges n'aient pas changé de manière significative qu'une carte numérique et qu'une radio ait ou non été disponibles, les participants ont eu recours à la communication vocale environ deux fois plus souvent lorsqu'ils avaient accès à une radio que lorsque cela n'était pas le cas. On a noté une importante différence sur le plan de la fréquence des échanges concernant la situation et l'emplacement dans les cas où l'on avait accès à un système de radiocommunication. Pour ce qui avait trait aux processus de l'équipe, les participants ont estimé qu'ils étaient plus conscients des pertes avec une carte imprimée qu'avec une carte numérique. Les participants ont estimé que la charge de travail perçue était considérablement moindre avec une carte numérique, qu'ils aient ou non été dotés d'une radio, bien qu'ils n'aient pas relevé de différence sur le plan du travail d'équipe.

Tant à l'occasion de questionnaires administrés au terme de l'exercice que de groupes de discussion, les participants se sont montrés nettement en faveur de la solution de la carte numérique et du système de radiocommunication. On a estimé que les radios permettaient d'améliorer considérablement le transfert de l'information, ainsi que la coordination tant au sein des groupes d'assaut qu'entre ceux-ci. On a estimé que les cartes numériques permettaient d'améliorer considérablement la prise de conscience quant à la situation géographique, ainsi que la coordination tant au sein des groupes d'assaut qu'entre ceux-ci. De manière générale, on a cependant estimé que, pour la plupart des fonctions des missions, il était plus important d'avoir une radio qu'une carte numérique, y compris pour connaître la situation sur le champ de bataille, la coordination avec la section, l'adaptation aux changements imprévus ainsi que la réduction des pertes. En fait, les radios ont été jugées très importantes pour la réussite générale de la mission, alors que les cartes numériques s'avéraient un peu moins importantes. D'autres évaluations s'intéressant particulièrement à l'utilité des cartes numériques et des radios durant les phases des missions ont démontré que les cartes numériques étaient le plus utiles durant la phase de briefing préalable à la mission, vraisemblablement pour la planification et du fait qu'elles permettaient de tracer les itinéraires de la mission. On a toutefois jugé que les radios étaient plus utiles que les cartes numériques lorsqu'il s'agissait de s'approcher de l'objectif et de donner l'assaut, ainsi que durant la phase de consolidation de la mission.

Il importe cependant de noter que la présente étude souffre d'une grave limitation potentielle qui découle des difficultés techniques auxquelles on a été confronté lors de sa réalisation. De manière plus spécifique, les systèmes de cartographie numérique n'ont pas très bien fonctionné, de telle sorte que le fait que les participants semblent avoir préféré pouvoir compter sur une radio plutôt que sur un système de cartographie numérique pourrait être directement imputable au piètre fonctionnement des systèmes utilisés pour les fins de la présente étude, auquel cas il ne représenterait pas une véritable évaluation de ce que de tels systèmes pourraient apporter aux opérations d'infanterie. En cela, il conviendra de reproduire les résultats de cette étude pour bien saisir la véritable utilité des systèmes de cartographie numérique.

Table of Contents

List of Tables

List of Figures

1. Background

This study is the fourth and final in a series investigating the impact of radio communication on small infantry teams for the Soldier Information Requirements Technology Demonstration (SIREQ-TD) project. The SIREQ cognitive task analyses identified the abilities to transfer information and to communicate between members in a dismounted infantry section as critical requirements for mission success. To overcome these current deficiencies in intra-section communications, most soldier modernization programs have adopted an intra-section radio as part of their hardware ensemble. As we have seen in previous studies, soldiers are overwhelmingly in favour of the intra-section radio in tactical assault missions both in the laboratory (see Adams, Tack, & Sartori, 2004a and Adams, Tack & Sartori, 2004b) and in the field (see Adams, Tack, & Thomson, 2004).

Ongoing technological developments have made the use of personal digital maps during missions possible. Possible advantages of providing such capability might include increased individual and/or collective situation awareness, reduced individual workload, and improved team coordination and execution. If some or all of these enhancements are realized by the addition of this equipment, it will be important to determine whether they improve overall performance. For example, soldiers may transmit fewer messages pertaining to their location when they have maps due to the *ad hoc* shared information. Moreover, by employing an alternative method of providing location information to soldiers (for example, by providing a visual display of the city map with all friendly force locations displayed), the pattern and content of the resulting radio communication might be altered. This alternative may affect situation awareness accuracy among section members and subsequently impact mission performance. Alternatively, section members may continue to use the radio just as frequently as before, and the addition of alternative information displays may reduce mission tempo, increase delays, and overload the attentional capacity of the soldiers. Clearly, these issues need further investigation.

The main purpose of the current study was to determine the effects of a digital map and/or radio on intra-section communication and performance in field tactical assault missions, and to elicit feedback about these systems. An earlier laboratory study (Adams, Tack & Sartori, 2004b) found that although workload perceptions were unaffected by the presence of a digital map, participants' perceptions of workload decreased when they had radios, and perceptions of teamwork increased. However, team performance measures showed no change with the addition of digital maps and radio communication within the laboratory setting. The following field study examined the impact of providing both digital map capabilities and radios to dismounted infantry teams in a wooded environment.

2. Aims

In this investigation, the following aims were pursued:

- To investigate the types, functions, and pathways of communications within a dismounted infantry section in the field, with and without digital maps and radios.
- To determine differences in communication concerning location in missions with and without a digital map.
- To explore how digital maps and radios compare to paper maps and no radios in the field, in terms of team performance and process. [3]
- To gather feedback from soldiers regarding the advantages and disadvantages of a digital vs. paper map, in combination with radios (and without radio) with respect to perceived impact on team process and performance and hardware.

[3] Although we had hoped to assess team performance, this could not be assessed, due to the failure of the SIMLAS system to record data reliably.

3. Method

This section gives an overview of the experimental method and explains the approach, data collection method and equipment used.

3.1 Overview

A nineteen-day field trial was undertaken in a wooded area ("E7") in Ft. Benning, Georgia over the periods 29 October – 14 November, 2002 and 2 March – 3 March, 2003. Thirty-two (n = 32) regular force infantry soldiers performed force-on-force tactical assault missions in wooded terrain. Each soldier was required to perform 2 section attacks using all four radio and map condition combinations (see Table 1) during the day.

Table 1: Experiment Conditions

	Radio	No Radio
DIGITAL MAP	✓	✓
PAPER MAP	✓	✓

For any one mission, eight soldier participants worked together as an organic infantry section, comprising two Assault Groups (AGs), to engage an enemy force of four soldiers occupying a defensive position in the wooded area. For each attack mission, soldiers maneuvered through the wooded area to their objective position. Weapons used included C7A1 personal weapons, blank firing, and a laser target engagement system, SIMLAS, to simulate live weapons effects and record engagements. Enemy forces were dressed in opposing force (OPFOR) dress and 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. Data collection included questionnaires and focus groups.

3.2 Equipment

3.2.1 Communications Network

Throughout the experiment, all soldiers used a Kenwood TK-280 radio as shown in Figure 1. The TK-280 measured 58mm x 135mm x 34mm (W x H x L) with KNB-16A battery, weighed 460g and met military environmental specifications. It had multiple scanning features that allowed users to scan other networks while set to send on a specific network.

Figure 1: The Kenwood TK-280 radio

To talk to other members of a network, a participant selected the network and depressed the PTT button and spoke into the boom microphone integrated into the helmet (see Figure 2).

Figure 2: Soldier with the radio equipment

A digital radio communications system had been developed to track and log all radio voice communications during each mission. The communications network comprised a central PC server connected to four base station receivers (see Figure 3 below).

The appropriate network base station receiver detected and transferred the voice communication to one of four soundcards resident in the PC server. The server logged the time, sender identification, network (thereby identifying the list of listeners), and stored a digital record of the communication in a WAV file.

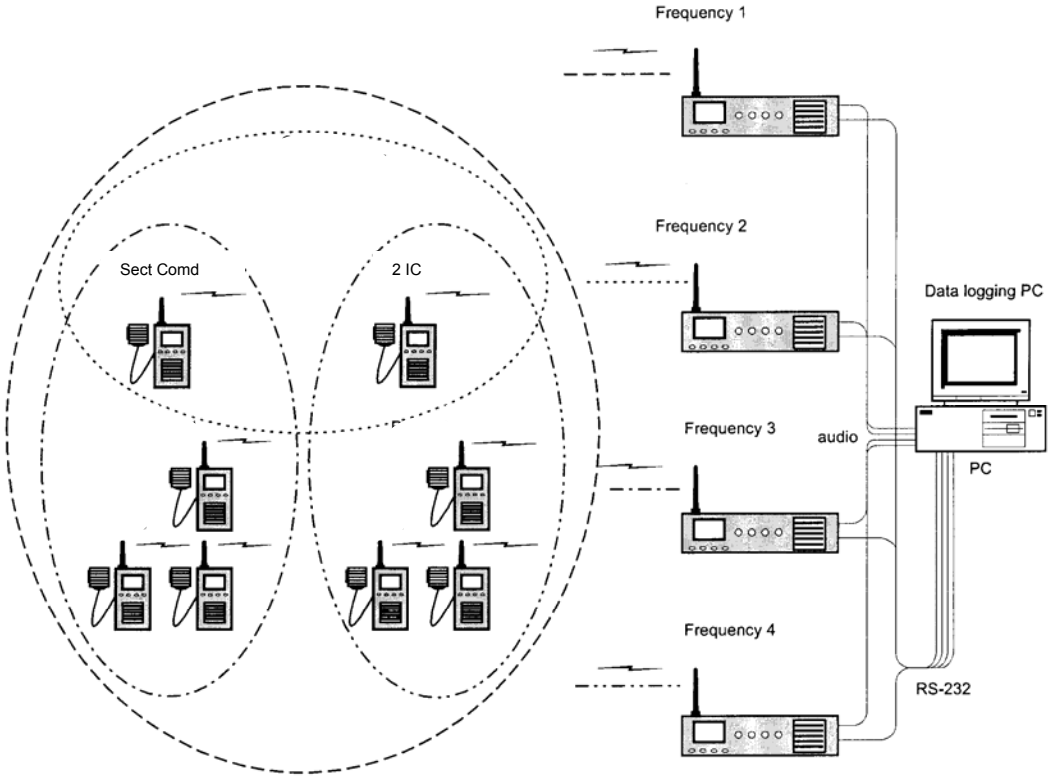

Figure 3: Communications Network

The TK-280 radios had four networks that were configured 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)

The digital map display was presented by a Xybernaut computer, and participants wore the display on their wrist (see Figure 4a and 4b). Digital maps presented on the computer showed the area where the relevant mission was being conducted with topography information, as well as real-time display of one's own position, and that of other section members.

Figure 4a: Xybernaut

Figure 4b: The components of the Xybernaut

A Garmin GPS receiver determined participants' position and a radio transmitter sent this information to the mobile instrumented vehicle (MIV). These data from all soldiers were then integrated and displayed as soldier icons on a common map or aerial photograph display. The MIV sent this imagery back to the individual soldier displays in real time.

3.3 Participants

Thirty-two (n = 32) regular force, dismounted infantry soldiers were organized into four sections. Participants included 2 Sgt., 3 MCpl., 11 Cpl., and 16 Pte. Participants were first assigned to 4 sections, and then each section was broken down into 2 AGs. Each section comprised a Section Commander (Sgt.), Second-in-Command (MCpl., Cpl.) and six soldiers (Cpl. or Pte. rank). Participant data were collected prior to the start of the experiment to characterize the subject sample and to provide a basis for matching AGs based on the profiles of soldiers in each group (i.e. to make the groups as similar as possible).

3.4 Experimental Conditions: Paper/Digital Map and Radio/No Radio

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

a) Paper Map Condition: The paper map condition included a map with terrain representation to reflect the current in-service method.

b) Digital Map Condition: Using a Xybernaut wearable computer with a digital tablet display strapped to the forearm,, each soldier was able to observe the real-time locations of each section member, overlaid on a map of the wooded area.

Radio Conditions: To evaluate the effects of providing intra-section voice communications, two communications network options were assessed in this experiment: a no radio option (i.e. current in-service method) and an open radio communications network.

a) No Radio Condition: In this option participants employed current in-service communications methods: soldiers used hand-signals, and spoke or yelled voice commands and replies depending on the requirements of the situation. Although the radio communication network was still actively recording, and participants were required to depress their push-to-talk (PTT) button during each voice exchange, radio volume was turned off. As such, participants were required to record the communication that they used in the no radio communication, but no other assault group members could actually hear them through the radio headset. The radio networks were monitored by experimenters to ensure that only communication "logging" rather than radio interaction was occurring. In the case of hand-signals, participants were instructed to depress their PTT and verbalize/record the hand-signal instruction.

b) Radio Condition: All four radio communication system networks 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 following radio network configuration:

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

Since the SC and the 2IC each led one of the two AGs they had access to three possible networks. The remaining riflemen had access to two networks (i.e. their AG and the larger Section Net).

3.5 Mission Description

The missions executed in this experiment provided a goal-oriented, team-based scenario in a contextually relevant small unit, infantry context. The experimental approach for each mission is outlined below, and aspects of the mission setup are described.

3.5.1 Outline Approach

All participants were briefed on the goals, mission structure, radio and digital map conditions, and protocol for the experiment. Following this, they were instructed in the use, installation, and operation of their SIMLAS equipment, and given the opportunity to undertaken head-to-head target engagements. Participants were also trained on the use of the digital map display and given an opportunity to operate and gain experience with the device, with other members of their section.

Following this, each mission comprised four phases.

Phase 1: Mission Briefing: Prior to the mission, the section was provided with execution orders, rules of engagement, a defined route and entry point for each AG, and limited information about the enemy at the objective. The mission brief was provided by the Lead Experimenter. Each mission employed small unit tactics to emphasize the issues of control within the section and within each AG, stealth during the approach, and coordination during the assault. Each mission was carefully configured to standardize the experimental mission parameters between conditions, within the context of tactics for wooded operations.

Phase 2: Mission Planning: The section was given the opportunity to study the map of the wooded area. Each Section Commander or AG leader then provided guidance or instructions to his group as required. The mission commenced and continued until the objective was reached or thirty minutes had elapsed.

Phase 3: Mission Execution: Based on the assigned orders, the section executed the mission using one of the four condition combinations. Each AG moved tactically with stealth along their assigned approach route. One AG was engaged enroute by enemy forces. This engagement required the AG to delay and coordinate their 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 or froze the mission to allow for the collection of status awareness data (Appendix A).

Having maneuvered to the objective, the two AGs began a coordinated assault.

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

3.5.2 Mission Maps

There were 10 mission maps in total used for this study. Each map consisted of a topographical map of the wooded area ("E7") at Fort Benning, Georgia.

3.5.3 Enemy

Enemy was used as a means of delaying and obstructing the AGs. This role was played by other soldiers from the 1st and 3rd Royal Canadian Regiment. By placing enemy in key locations, enemy presence would require the two AGs to use communication to coordinate their movements and their fire. As noted earlier, enemy force soldiers were also outfitted with SIMLAS laser target engagement systems to record weapons engagements. Enemy forces wore opposing force (OPFOR) dress.

3.5.4 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 the freeze and were regenerated before the mission resumed. Any AG casualties after the freeze were not regenerated.

3.6 Dependent Measures

Data were collected before, during and at the end of each mission, as well as at the start and end of the experiment.

3.6.1 Mission Freeze

During the course of each mission, the assault was paused and participants were queried for the following status awareness information.

a) Status Awareness: At a critical stage of the mission (e.g. immediately following an engagement with the enemy) the assault paused and participants indicated their awareness of the following factors in the other AG.

- Awareness of casualties in other AG: The number of casualties (0 to 4).
- Awareness of RV timing: The time that soldiers believed they would arrive at the RV, (4 point scale, ranging from very early to very delayed).
- 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), likelihood of mission success (4 point scale, ranging from very unlikely to very likely).

3.6.2 Throughout each Mission

The following data were collected throughout the course of each mission.

a) Communication Measures: Using the data capture capabilities of the voice communications LAN and a review of mission activities, each voice message was categorized for the following variables. The voice communications measurement approach has been adapted from Entin (1993).

Using a post-hoc semantic analysis of the content of each voice message, messages were classified according to the following criteria.

- Type: Messages were first type classified as either 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". Those communications, such as "Comms Check", "Prestle Stuck", requesting the "Experimenter", "Keystroke", "Invalid File Type", or "Purely Social" communications were classified as "Other" throughout the report.
- 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".
- Enemy / Friendly: For functions involving "Status" or "Location", the message was further classified as relating to "Enemy" or "Friendly" forces.

For 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.

- 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.

Anticipation ratios were also measured.

- 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).

3.6.3 End of each Mission

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

a) Teamwork Measures: Participants completed a Teamwork Questionnaire (Appendix A) to assess the performance of each section for a variety of teamwork dimensions: e.g. team communication, anticipation of information needs, coordination, and team orientation. Participants rated teamwork on a 7-point Likert scale where 1 equalled "Strongly Disagree" and 7 equalled "Strongly Agree".

b) Mental Workload: Participants completed a NASA TLX Questionnaire (Appendix A), indicating the levels of subjective workload experienced during the mission. The NASA TLX required participants to rate six measures of mental 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".

3.6.4 End of the Experiment

After completing all missions in each radio communication and digital map display condition, participants completed an Exit Questionnaire (Appendix A), which determined participants' acceptability ratings for the radio vs. no radio and digital map vs. paper map. 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).
- The implications of an information exchange network on small team tactics.

3.6.5 Experimental Schedule

The experiment was initially scheduled to be completed within the timeframe of the Benning IV experimentation series. Several challenges encountered made this impossible. These challenges included serious technical difficulties with the Xybernauts (e.g. overheating, PCI cards becoming unseated, and losing the network connection), to problems with the GPS systems not working properly (due to satellite scrambling before the Iraq war began). This necessitated returning during Benning V to complete one final set of missions with a similar section.

3.7 Briefings/Training

Soldiers were instructed in the use, installation, and operation of their SIMLAS equipment. They were also trained on the use of the radios and digital maps, and given an opportunity to practice operating within their assault groups and in conjunction with other members of their section.

3.8 Daily Experimentation

During each experimentation day, soldiers engaged in up to six missions. Thus, each section participated in the experiment for two days, and each section completed 2 missions in each of the 4 test conditions. The breakdown of the timing of each phase of the missions was as follows:

Mission Brief	10 minutes
Section Planning	15 minutes
Mission Execution (including mission freeze)	30 minutes
Endex Measures	15 minutes

The mission brief was provided by the Lead Experimenter, who detailed mission goals, timings, AG routes, an outline plan of execution, and enemy status. Next, fifteen minutes were allotted for the section to review the mission map and for the SC to create his plan. When this process was complete, the mission was started. The mission continued until the predefined point at which one of the enemy forces was killed. At this point, the mission "froze" and measures of situational awareness were completed. The mission then resumed until the objective was reached or thirty minutes had elapsed. Following the mission, soldiers completed the Endex questionnaires and all mission data were logged and archived.

3.9 Wrap-up Session

The final day included a half-day set aside for completing missed missions or repeating any missions. The final focus group discussion was held at the completion of all testing.

3.10 Data Analysis

As each soldier completed two missions in each of the 4 test conditions, statistical analyses used a crossed repeated measures design with the map condition (digital or paper), and communication condition (radio or no radio) as within-subject factors.

4. Results

4.1 Overview of Communications

Table 2 presents the total number of wave files, the total number of transmissions (discrete thoughts), and the mean transmissions across missions and standard deviation for each of the 4 conditions. Note that the N of 8 represents 4 Sections of soldiers conducting 2 missions in each of the 4 test conditions.

Table 2: Wav files and transmissions[4]

	N	# of wav files	# of transmissions	Mean transmissions across missions
Paper/No Radio	8	916	755	94 ± 54.4
Paper/Radio	8	1677	1600	200 ± 48.6
Digital/No Radio	8	1088	885	98 ± 57.9
Digital/Radio	8	1765	1779	198 ± 103.7
Total	32	5446	5019	

Overall, there were a total of 5446 wave files and 5019 discrete transmissions across the 4 conditions and 32 missions. In general, the communication was more frequent when the AGs had radios than when they did not. Soldiers communicated approximately two times more often when they had a radio than when they did not.

Figure 5 shows the proportion of total number of transmissions in the four conditions.

[4] The large disparity between the number of wav files (all recorded files) and transmissions (all identifiable communications) in the no radio condition is important to address. In this field trial, the communication capture system showed a number of anomalies not seen in the laboratory. Key amongst these was the recording of duplicate wav files when multiple users hit the prestle at the same time. These files (and those with similar problems) were excluded from coding, as they contained either redundant or unidentifiable communications. Although the rates at which these files occurred in all 4 conditions were similar, the number of transmissions in the average wav file in the no radio condition was lower, creating this disparity.

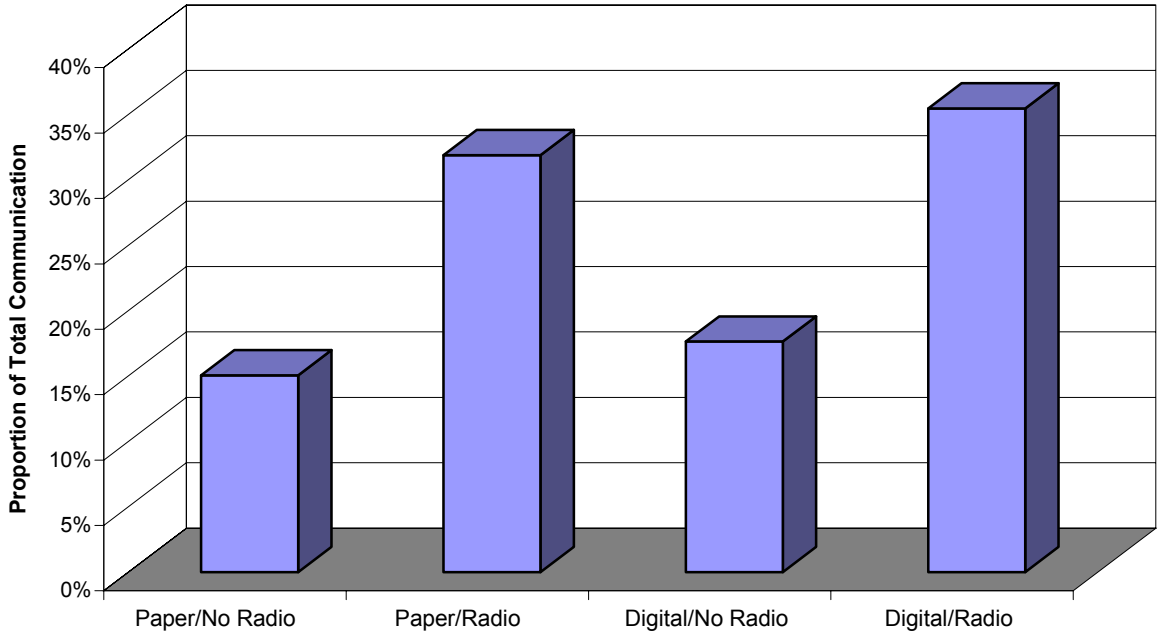

Figure 5: Breakdown of total communication by condition

As the chart 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 4 conditions.

4.1.1 Type of Communication

Consistent with the previous three studies (Adams, Tack & Sartori, 2001a; Adams, Tack &Thomson, 2002; and Adams, Tack & Sartori, 2002b), we were interested in determining whether or not the type of communication changes when soldiers have a radio vs. not having a radio coupled with having a digital map vs. a paper map. Previous studies have shown that having a radio compared to not having a radio changes the frequency of certain types of communication. In Adams, Tack and Sartori (2004a), there was a noticeable change in communication type. When soldiers did not have a radio, they tended to limit their communications to orders and transfers of information. Indeed, soldiers had approximately two times the amount of orders compared to soldiers with a radio (Adams, Tack & Sartori, 2004a). On the other hand, those who carried a radio showed more differentiated communication, including an increase in transference of information, requests and acknowledgements. Similarly, though to a lesser degree, in Adams, Tack and Thomson (2004), there were fewer orders and more transfers and acknowledgements when soldiers carried a radio compared to when they did not. A recent laboratory study (Adams, Tack & Sartori, 2004b), comparing a radio vs. no radio condition coupled with a digital map vs. paper map condition, also demonstrated a higher number of orders when soldiers conducted assault missions without a radio irrespective of map condition. Acknowledgements also increased when soldiers had a radio.

As shown in Figure 6 raw frequencies showed that most types of communications occurred more frequently in the radio conditions than in the no radio conditions.

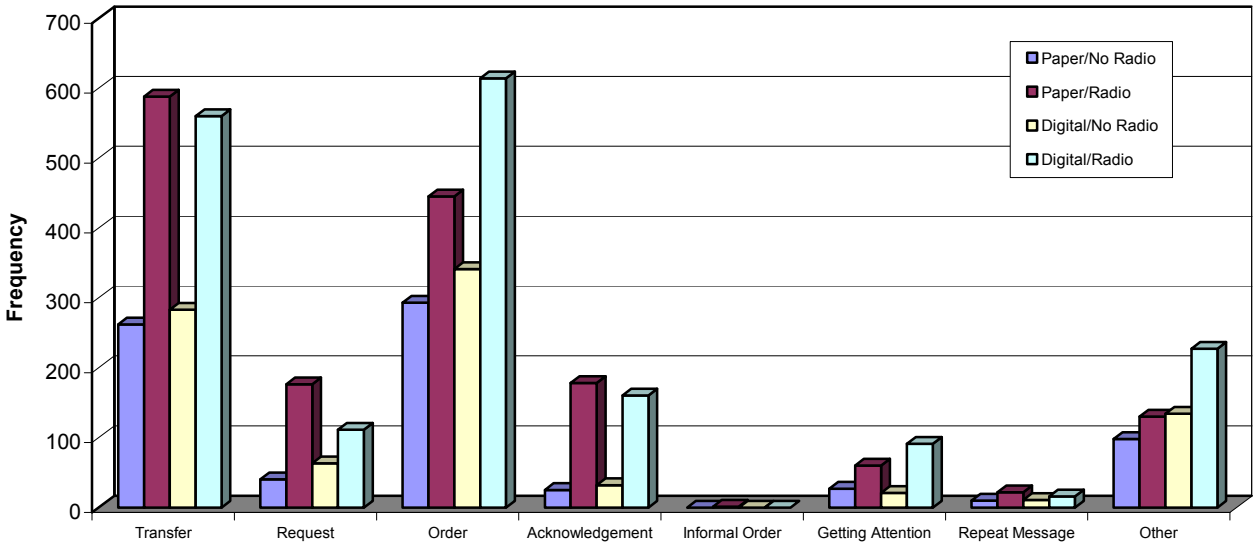

Figure 6: Frequency of type of communication by condition

There are obvious differences in the frequency of specific types of communication among conditions, due to differences in overall communication rates within each condition. As such, in order to compare amongst conditions, it is important to consider the relative proportion of each type of communication within each condition (i.e. raw frequency over total frequency within the condition). This is depicted in Figure 7.

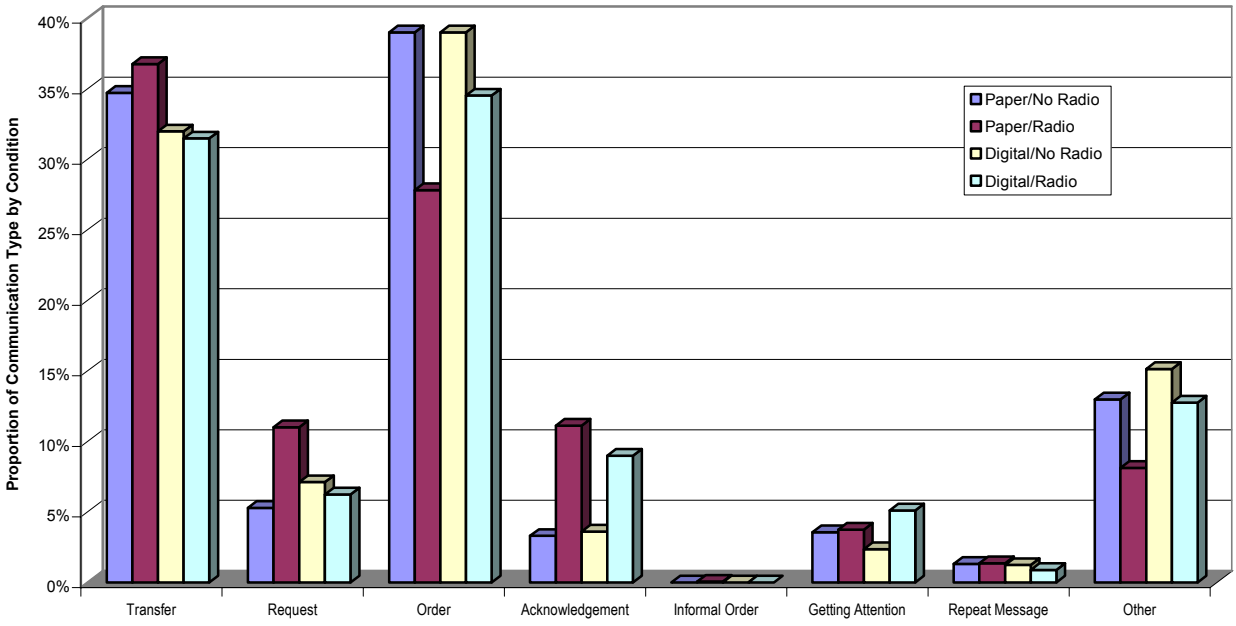

Figure 7: Type of communication by condition[5]

Figure 7 shows the proportion of each type of communication in each condition. The most frequent type of communication in the Digital/No Radio, Paper/No Radio and Digital/Radio were orders, with 39%, 39% and 35% respectively. The Paper/Radio condition had fewer orders, comprising only 28% of its total communication transmissions; transfers of information were the most frequent communication type in this condition with 37%. Transfers of information made up 35% of the Paper/No Radio condition, 32% of the Digital/No Radio condition and 31% of the Digital/Radio condition. The Paper/Radio condition had more requests than the other 3 conditions. As well, the Paper/Radio and Digital/Radio conditions had more acknowledgments than the other two No Radio conditions.

Like the previous studies, when comparing radio vs. no radio conditions, orders were more frequent in the no radio conditions, whereas acknowledgements were more frequent in the radio conditions. These results were most salient in the paper map conditions, including requests where there were twice as many in the Paper/Radio condition compared to the Paper/No Radio condition. In the paper map conditions, there were more transfers of information compared to the digital conditions. The Paper/Radio condition had fewer orders compared to the Digital/Radio condition. Overall, differences in the type of communication are more the result of the introduction of a radio and not the digital map.

[5] The "Other" category relates to communication that could be identified, but which did not contain mission relevant intra-section communication. Annex A shows a breakdown of the types of transmissions within this category.

4.1.2 Function of Communication

It is also important to consider whether different conditions yield different function-related communications. In the original laboratory study (Adams, Tack & Sartori, 2004a), participants without a radio provided more communication relating to their location than soldiers with a radio. On the other hand, comparing no radio vs. radio function-related communications, Adams, Tack and Thomson (2004) found little difference across conditions. Furthermore, Adams, Tack and Sartori (2004b) also showed little difference despite the introduction of a map vs. no map condition.

As shown in Figure 8, the frequency of transmissions related to status, location, and task assignment were higher in the radio conditions compared to the no radio conditions.

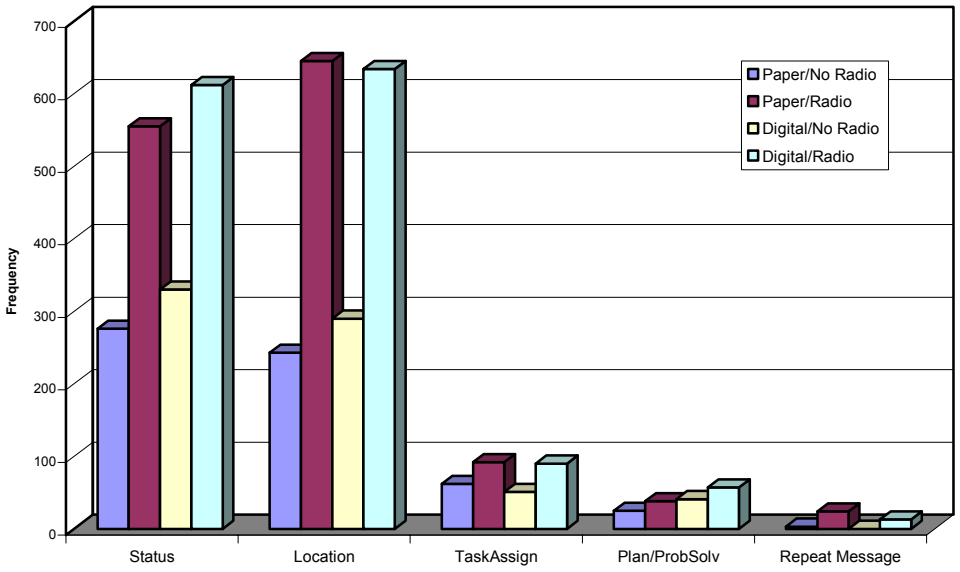

Figure 8: Frequency of function communication by condition

When soldiers carry radios, they communicate their status and location far more frequently than when they do not have radios.

As Figure 9 illustrates, transmissions regarding location and status were the two most common function-related communications, followed by assignment of tasks.

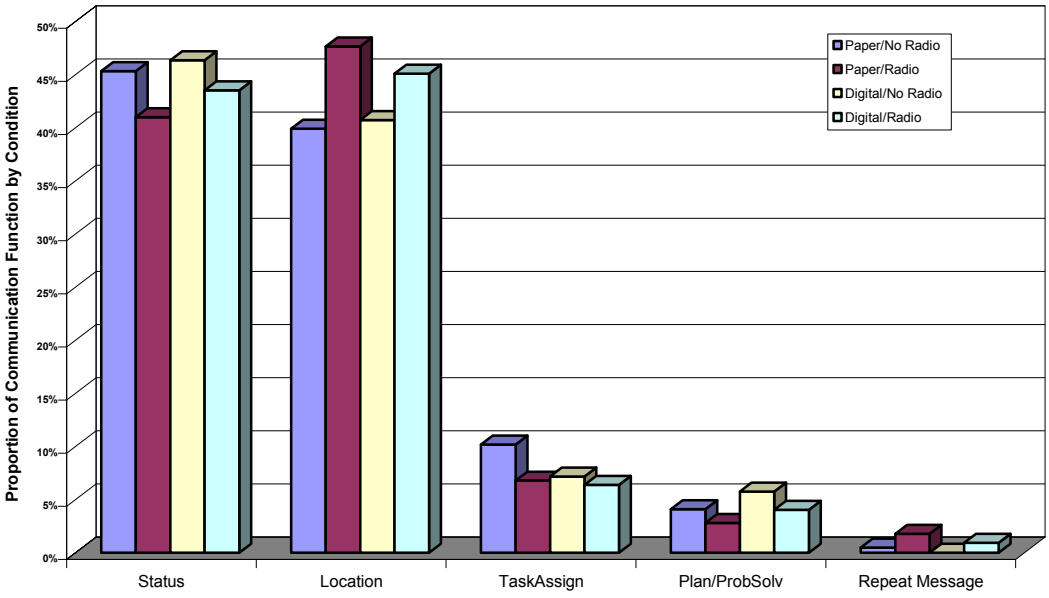

Figure 9: Function of communication by condition

There were more communications relating to status in the no radio conditions compared to the radio conditions, though this was only marginal. In the Digital/No Radio condition, 46% of communication related to soldiers' status. The Paper/No Radio condition had 45%. On the other hand, 44% of the function-related communication concerned status in the Digital/Radio condition and 41% in the Paper/Radio. There was a greater number of communications relating to location in the two radio conditions, with 45% in the Digital/Radio condition and 48% in the Paper/Radio condition. Again, this difference was marginal. The frequency in the Digital/No Radio was 41%, and in the Paper/No Radio it was 40%. These differences are most pronounced when the Paper/Radio and Paper/No Radio conditions are compared. Further digital map proficiency and improved experimental conditions may see a greater difference in the amount of communications regarding location in the Digital/No Radio condition compared to the Digital/Radio condition.

Communications that related to assigning tasks were most frequent in the Paper/No Radio condition compared to the other three conditions. Communications that related to planning and problem solving were most frequent in the Digital/No Radio condition compared to the others.

4.1.3 Combined Type and Function

Most transmissions have information relevant to both type and function. Table 3 below lists the most frequent occurrences of forms of communication noted during the missions and their relative frequencies across the 4 conditions.

Table 3: Combined type by function frequencies

Form of communication	Paper/No Radio	Paper/Radio	Digital/No Radio	Digital/Radio
Transfer of location	20%	25%	18%	19%
Transfer of status	21%	16%	18%	19%
Order regarding status	19%	13%	22%	17%
Order regarding location	18%	14%	17%	19%
Requesting status	2%	4%	3%	2%
Acknowledging location	0%	5%	2%	4%
Requesting location	2%	4%	3%	2%
Acknowledging status	1%	4%	1%	3%

In the previous studies (Adams, Tack & Sartori, 2004a and Adams, Tack & Thomson, 2004), the most frequent type and function-related communication was orders regarding location. In the current study, however, a transfer of location was the most frequent form of type and function-related communication for the Paper/Radio condition with 25%, followed by transfer of status with 16%. Transfer of location was also most frequent with the Digital/Radio condition with 19%. There were as many transfers of status in this condition as well. Twenty-one percent of type and function-related communications in the Paper/No Radio condition were transfers of status and 20% were transfers of location. The most frequent type and function-related communication in the Digital/No Radio condition was orders regarding status. Orders regarding status and location were also fairly high in the four conditions, though not number one.

4.1.4 Friendlies vs. Enemies

Each unit of communication was also categorized as to whether it described friendly forces, enemy forces, or undefined forces. As Figure 10 demonstrates, the frequencies of references to friendly and enemy forces were higher in the radio conditions than in the no radio conditions.

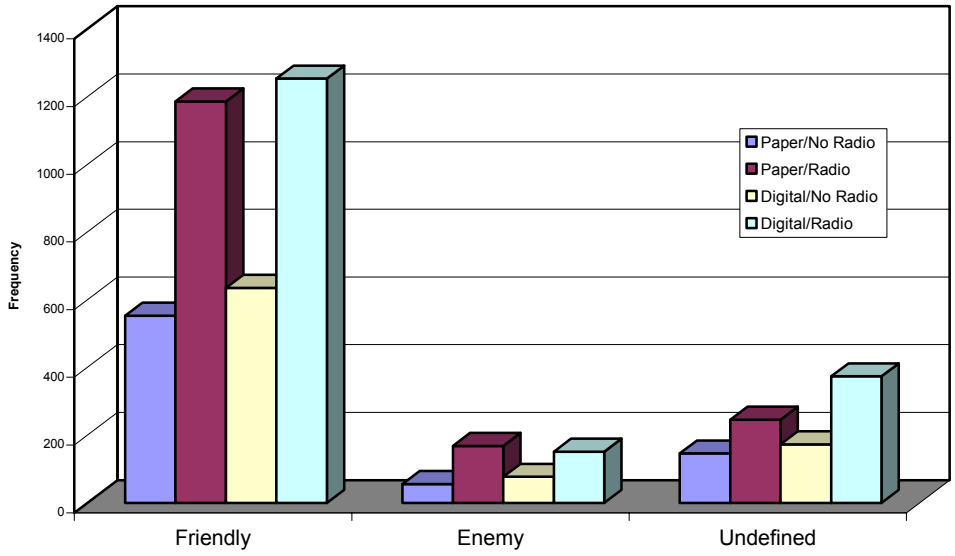

Figure 10: Frequency of friendly/enemy references by condition

In terms of relative proportions, however, there was very little difference across both radio and map conditions (see Figure 11).

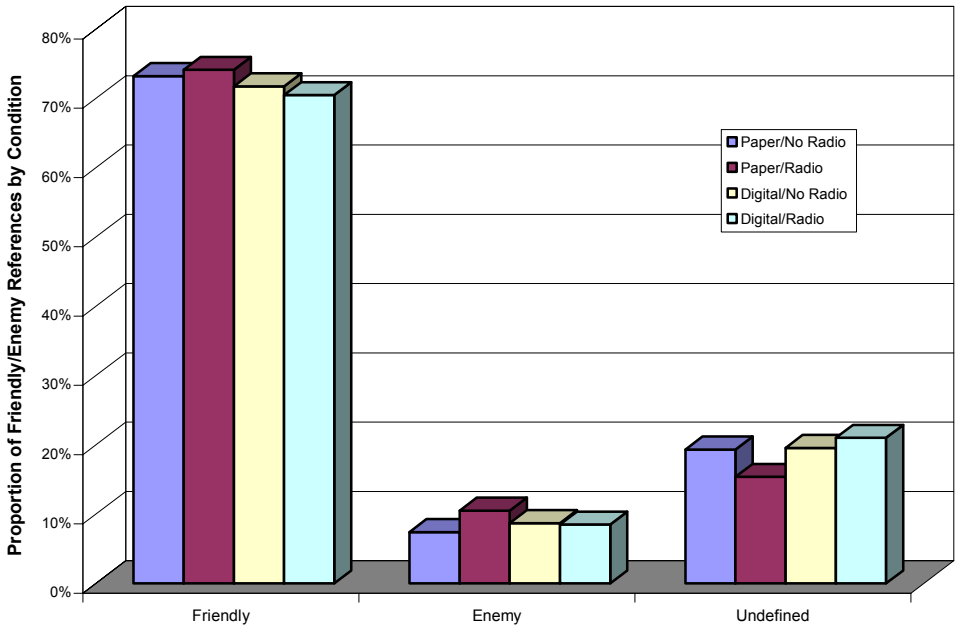

Figure 11: Friendly/enemy references by condition

Similar to the previous studies (Adams, Tack & Sartori, 2004a; Adams, Tack & Thomson, 2002; and Adams, Tack & Sartori, 2004b), in all of the conditions, the references to friendlies were by far the highest. On the other hand, there were more communications with a reference to undefined forces in this study compared to the previous three studies. This is likely a result of the experimental conditions. Where the previous studies were conducted in an urban setting, this study was conducted in a wooden terrain.

4.2 Pathways of Communication

As a result of the similar pattern demonstrated throughout the previous three reports (Adams, Tack, and Sartori, 2004a; Adams, Tack, and Thomson, 2004; and Adams, Tack, and Sartori, 2004b), and because the focus of this study was how the advent of the digital map changes soldiers status awareness and other team processes, we did not explore the proportion of communication type according to roles. Instead, to understand the pathways of communication, we looked at the frequency of communication according to network radio communication.

As mentioned in the method section, four different radio networks were created, which allowed soldiers in different roles to choose the network over which they would communicate with others. Table 4 shows the frequency of radio transmissions over each of the 4 networks.

Table 4: 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

As illustrated in Figure 12, network 4, the all section members net, was the most frequently used radio network for communication.

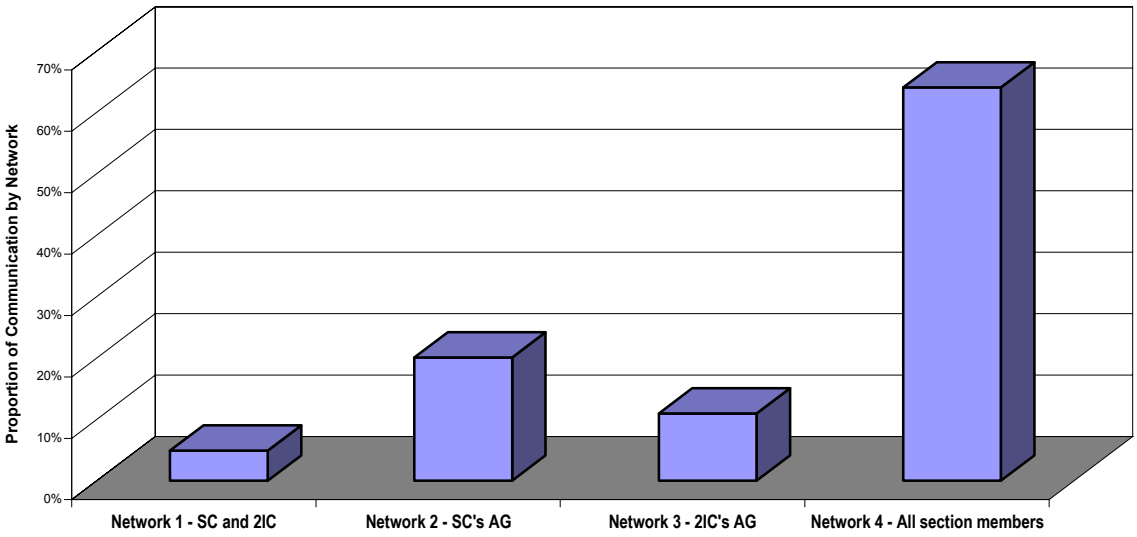

Figure 12: Breakdown of radio network communication

This finding was different than those in Adams, Tack, and Sartori (2004b) where section members used the AG networks more often than the all members net and the private leaders net. It might be more efficient to have all members connected when performing tactical assault missions in the field as opposed to a laboratory 1st person gaming environment.

4.3 Anticipation Ratios

The ability of team members to anticipate the information needs of other members is an indication of teamwork and coordination (Sperry, 1995). Anticipation ratios provide 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) (e.g. Sperry, 1995). Anticipation ratios are calculated using the ratio of transfers to requests. Sperry (1995) represents this quotient with a numerator only; the denominator is understood to be 1. Thus, for example, an anticipation ratio of 1.63 indicates that a team's transfers exceeded their requests, 1.63 to 1. A ratio of 1.00 or more is indicative of anticipation behaviour. Similarly, a ratio of less than one indicates that team members have requested more information than has been given. This may be a sign of less effective team communication.

Previous studies showed that soldiers anticipated the information needs of other members, indicating teamwork and coordination. However, the difference across conditions was only salient in Adams, Tack, and Sartori (2004a). This study revealed quite a difference in anticipation ratios when comparing radio and no radio conditions because, in the latter condition, there were far fewer requests compared to when soldiers had radios.

We compared whether AGs showed different patterns of anticipatory communication as a result of the radio vs. no radio condition coupled with the digital vs. paper map condition. The results are shown in Table 5.

Table 5: Anticipation ratios across conditions

Frequency	Paper/No Radio	Paper/Radio	Digital/No Radio	Digital/Radio
Transfers	262	588	283	560
Requests	40	176	63	111
Anticipation Ratio	6.6	3.3	4.5	5.0

In this study, soldiers anticipated the information needs of the other members of the section. In the Paper/No Radio condition, there was a high anticipation ratio, 6.6 compared to the Paper/Radio condition, 3.3. For the Paper/No Radio condition, the relatively high anticipation ratio may represent a procedural form of redundancy. Perhaps this represents 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.

Table 6 shows that there was an anticipation of information across all networks.

Table 6: Anticipation ratios across networks

Frequency	SC and 2IC	SC's Assault Group	2IC's Assault Group	SC and 2IC with AG listening
Transfers	85	355	174	1079
Requests	25	92	35	238
Anticipation Ratio	3.4	3.8	4.9	4.5

4.4 Team Process Measures

Team processes, such as status awareness, teamwork, and workload may vary with the introduction of both a digital map and radio communications. In earlier studies with digital maps and radio, contrary to expectations, workload was rated significantly lower with a radio than without (Adams, Tack & Sartori, 2004b).

Status awareness: Participants were asked to estimate the number of casualties they expected within their own assault group (from 0 to 4), and to estimate the RV timing and the assault completion timing (ranging from 1 "very early" to 5 "very delayed") from "very early" (represented as "1" on the table) to "very delayed" (represented as "5" on the table). These results are shown in Table 7.

Table 7: Status awareness items

Mean (StDev)	Paper/No Radio	Paper/Radio	Digital/No Radio	Digital/Radio	Sig. Differences
Awareness of Casualties	0.6 ± 0.9	1.1 ± 1.2	0.7 ± 1.1	0.4 ± 0.7	Map significant, Paper > Digital
Awareness of RV Timing	3.0 ± 0.5	3.2 ± 0.6	3.1 ± 0.6	3.2 ± 0.8	ns
Awareness of Assault Completion	3.0 ± 0.6	3.1 ± 0.6	3.2 ± 0.4	3.1 ± 0.6	ns

As shown in Table 7, participants rated their awareness of casualties significantly higher in paper map missions than in digital map missions. Figure 13 shows the relevant means, standard deviations and standard errors. There were no other significant main effects or interactions.

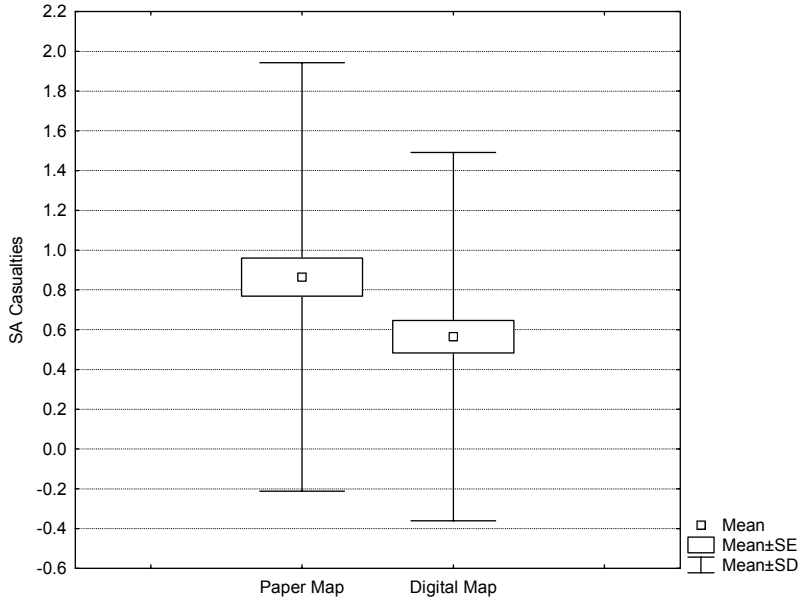

Figure 13: Status awareness – casualties

Ratings of status awareness for RV timings and for awareness of assault completion did not differ significantly as a function of having (or not having) maps and radios.

Workload: Participants also completed a NASA TLX questionnaire, indicating the levels of subjective workload experienced during the mission. This version requires the participant to rate six measures of mental workload on an 18-point scale ranging from high (where 18 represents demand, complexity) to low (where 1 represents easy, simple).

Table 8: Workload

Mean (StDev)	Paper/No Radio	Paper/Radio	Digital/No Radio	Digital/Radio	Sig. Differences
Index	6.1 ± 2.9	6.5 ± 2.7	5.8 ± 2.7	5.5 ± 2.5	Map significant Digital < Paper

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 (see Figure 14). There were no other significant main effects or interactions.

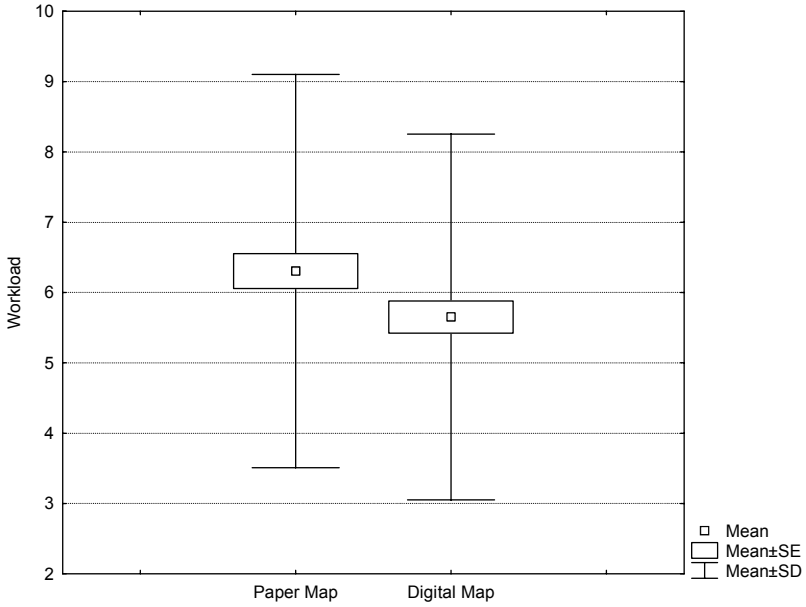

Figure 14: Workload

Teamwork: Participants completed a teamwork questionnaire to assess the performance of each AG, and the section as a whole, for a variety of teamwork dimensions including anticipation of information needs, coordination, communication behaviour, monitoring behaviour, feedback behaviour, backup behaviour, and team orientation. They rated the degree to which they agreed with several teamwork statements using a 7 point Likert scale where 1 represented "Strongly Disagree" and 7 represented "Strongly Agree". The mean and standard deviation are presented in Table 9.

Table 9: Teamwork

Mean (StDev)	Paper/No Radio	Paper/Radio	Digital/No Radio	Digital/Radio	Sig. Differences
Index	5.4 ± 1.0	5.5 ± .9	5.4 ± 1.0	5.2 ± 1.0	ns

As Table 9 shows, teamwork ratings were relatively high across all conditions, but were no significant differences in perceptions of teamwork.

4.5 Exit Questionnaires and Focus Group

At the end of the missions, participants completed the exit questionnaire and participated in a focus group. Researchers were interested in identifying soldiers' overall perceptions regarding information transfer, coordination between and within AGs when soldiers carried a radio. Furthermore, researchers were interested in identifying soldiers' overall perceptions regarding location awareness, AG coordination, section coordination, and overall acceptance when they carried a digital map compared to a paper map.

For all questionnaire items, soldiers were asked to rate their opinions on 7-point scales from 1 "Completely Unacceptable" to 7 "Completely Acceptable". All items were analyzed using dependent t-tests and significant differences are indicated.

4.5.1 Radio versus No Radio

Information Transfer: As shown in Table 10, soldiers completed rating scales assessing the acceptability of the radio communication systems for transfer of information, or using current operational procedures without enhanced communication capabilities.

Table 10: Information transfer

Mean(StDev)	No Radio	Radio	Sig. Differences
Amount of information that can be passed	4.4 ± 1.2	6.4 ± 0.8	Radio > No Radio
Time required to pass information	4.2 ± 1.3	6.4 ± 0.6	Radio > No Radio
Timeliness for initiating comms	4.6 ± 1.3	5.9 ± 1.1	Radio > No Radio
Ease of passing information	4.3 ± 1.3	6.1 ± 1.0	Radio > No Radio
Ease of requesting information	3.7 ± 1.4	6.3 ± 0.7	Radio > No Radio
Ease of receiving information	4.1 ± 1.3	6.3 ± 0.6	Radio > No Radio
Ease of getting acknowledgement of information received	4.2 ± 1.5	6.2 ± 0.9	Radio > No Radio
Ease of getting acknowledgement of information understood	4.3 ± 1.4	6.3 ± 0.8	Radio > No Radio
Accuracy of information passed	4.4 ± 1.4	6.2 ± 0.8	Radio > No Radio
Message detail possible	3.7 ± 1.5	6.3 ± 0.8	Radio > No Radio

Soldiers found all of the information transfer capabilities to be more acceptable with a radio than without.

Coordination and Awareness Within and Between Assault Groups: Having radio communications may also impact the ability of section members to coordinate their actions. Soldiers' ratings of overall coordination within and between their AGs in the radio and no radio conditions are presented in the tables below.

Results in Table 11 show that soldiers rated within AG coordination and awareness significantly better with a radio than without.

Table 11: Coordination within AG

Mean(StDev)	No Radio	Radio	Sig. Differences
Coordination of movement	5.1 ± 1.0	6.3 ± 0.6	Radio > No Radio
Coordination of fire	5.2 ± 0.9	6.1 ± 0.8	Radio > No Radio
Coordination of action	5.1 ± 1.0	6.3 ± 0.7	Radio > No Radio
Issuing/receiving orders	5.2 ± 1.0	6.4 ± 0.6	Radio > No Radio
Designating targets	5.3 ± 0.9	6.0 ± 1.0	Radio > No Radio
Ease of distributing message within Assault Group	4.8 ± 1.2	6.3 ± 0.8	Radio > No Radio
Awareness of location of your Assault Group members	5.2 ± 1.2	6.2 ± 0.6	Radio > No Radio
Awareness of casualties among your Assault Group members	4.8 ± 1.2	5.9 ± 1.0	Radio > No Radio
Awareness of ammunition usage of your Assault Group	4.7 ± 1.4	5.9 ± 1.0	Radio > No Radio

Soldiers also rated coordination and awareness between AGs significantly better with a radio than without (Table 12).

Table 12: Coordination between AGs

Mean(StDev)	No Radio	Radio	Sig. Differences
Coordination of Assault Group movement	4.2 ± 1.4	6.3 ± 0.6	Radio > No Radio
Coordination of Section fire	4.7 ± 1.3	5.9 ± 0.8	Radio > No Radio
Coordination of Section action	4.6 ± 1.3	6.1 ± 0.6	Radio > No Radio
Issuing/receiving orders	4.6 ± 1.3	6.3 ± 0.7	Radio > No Radio
Designating targets	4.7 ± 1.2	6.1 ± 0.6	Radio > No Radio
Ease of distributing message within Section	4.2 ± 1.4	6.4 ± 0.6	Radio > No Radio
Awareness of location of the other Assault Group	3.3 ± 1.6	6.3 ± 0.7	Radio > No Radio
Awareness of casualties of the other Assault Group	3.1 ± 1.5	6.2 ± 0.8	Radio > No Radio
Awareness of ammunition usage of other Assault Group	3.0 ± 1.6	5.9 ± 1.0	Radio > No Radio

Participants were also asked to compare the acceptability of a radio overall vs. not having a radio, as shown in Table 13.

Table 13: Overall acceptance of the radio condition

Mean(StDev)	No Radio	Radio	Sig. Differences
Overall acceptance	4.2 ± 1.1	6.3 ± 0.6	Radio > No Radio

Overall, participants' acceptance level of the radio was significantly higher than the acceptability of not having radio (Table 13). These results clearly support the notion that having a section radio is likely to be important for both coordination and for information transfer.

4.5.2 Paper Map versus Digital Map

Location Awareness: Having a digital map is likely to affect soldiers' awareness of the location of various parties. Soldiers were asked to rate the acceptability of having a digital map compared to a paper map for awareness of their own location, their own AG members' locations and the other AG's location. The means and standard deviations are presented in Table 14.

Table 14: Location awareness

Mean (StDev)	Paper Map	Digital Map	Sig. Differences
Awareness of own location	5.1 ± 1.0	6.7 ± 0.5	Digital > Paper
Awareness of location of your Assault Group members	5.1 ± 1.2	6.6 ± 0.5	Digital > Paper
Awareness of location of the other Assault Group	3.1 ± 1.4	6.6 ± 0.5	Digital > Paper

Soldiers rated the digital map as significantly more acceptable for all aspects of location awareness compared to a paper map (see Table 14).

Coordination: Having the ability to view oneself and other section members on a digital map display should also improve the coordination of various aspects of the missions. The results from these questionnaire items concerning aspects of their own AG operations are presented in Table 15.

Table 15: Coordination within AGs

Mean (StDev)	Paper Map	Digital Map	Sig. Differences
Coordination of movement	5.3 ± 0.8	5.8 ± 1.1	Digital > Paper
Coordination of fire	5.5 ± 0.9	5.8 ± 1.0	Digital > Paper
Coordination of action	5.5 ± 0.8	6.1 ± 0.9	Digital > Paper
Issuing/receiving orders	5.6 ± 0.8	6.0 ± 1.0	Digital > Paper
Designating targets	5.3 ± 0.9	5.9 ± 0.8	Digital > Paper
Sharing information	5.3 ± 1.2	5.9 ± 0.9	Digital > Paper

Table 15 shows that soldiers rated having a digital map significantly more acceptable than having a paper map for coordination with their own AG. They rated having a paper map as borderline acceptable and having a digital map as reasonably acceptable for each item. Similar results were found for the coordination of the section as a whole as shown in Table 16.

Table 16: Coordination between AGs

Mean (StDev)	Paper Map	Digital Map	Sig. Differences
Coordination of Section movement	4.9 ± 1.2	6.3 ± 0.7	Digital > Paper
Coordination of Section fire	5.0 ± 1.1	5.8 ± 0.8	Digital > Paper
Coordination of Section actions	5.2 ± 1.0	6.0 ± 0.7	Digital > Paper
Sharing information	4.8 ± 1.4	6.0 ± 0.8	Digital > Paper
Ability to maintain mission tempo	5.1 ± 1.3	5.8 ± 0.9	Digital > Paper
Ability to meet mission timings	5.2 ± 1.1	5.9 ± 0.9	Digital > Paper
Anticipating the action of the other Assault Group	4.1 ± 1.6	6.1 ± 0.8	Digital > Paper

Table 16 above shows that soldiers rated having a digital map significantly more acceptable than a paper map for coordination between AGs. Specifically, they rated the digital map as barely to reasonably acceptable, but having a paper map as reasonably to barely unacceptable.

Table 17 shows soldiers' overall acceptance level for the digital map compared to the paper map.

Table 17: Overall acceptance of maps

Mean (StDev)	Paper Map	Digital Map	Sig. Differences
Overall acceptance	5.0 ± 1.0	6.1 ± 0.7	Digital > Paper

Again, having a digital map system was seen as very important by soldiers both overall, and important for the provision of location information and AG coordination.

4.5.3 General Statements Regarding Digital Maps and Radios

Finally, soldiers were provided with a number of statements. They were asked to indicate whether they agreed or disagreed where 1 represented "Strongly Disagree" and 7 represented "Strongly Agree". The results are found in Table 18.

Table 18: Soldiers' level of agreement with radio comms and digital maps

Mean (StDev)	Participant Agreement
We were more effective as a team with the radio communication system than with the no radio system.	6.2 ± 0.7
All members of a dismounted infantry Section should be provided with radio comms during a mission.	6.4 ± 0.7
We were more aware of our situation with the no radio system than with the radio comms system.	2.2 ± 0.9
Assault Group command and control were improved with the radio comms system, over the no radio system.	6.3 ± 0.6
Section command and control were improved with the no radio system, over the radio comms system.	2.3 ± 1.3
The digital map was more useful than the paper map.	5.2 ± 1.5
We were more aware of our situation with the digital map system alone than with the radio comms system alone.	4.7 ± 1.6
Assault Group command and control were improved with the digital map alone, over the radio comms system alone.	3.7 ± 1.5
Section command and control were improved with the radio comms system alone, over the map system alone.	4.4 ± 1.7
With a digital map system, we did not need to use the radio comms system as often.	3.4 ± 1.8
All members of a dismounted infantry Section should be provided with a digital map during a mission.	3.5 ± 1.7
All members of a Section should be provided with **both** a radio and a digital map during a mission.	4.0 ± 1.8

Soldiers agreed that the introduction of a radio improved their section's effectiveness to work as a team, enhanced command and control, and provided greater awareness of their situation. They also agreed that all members of a dismounted infantry section should have radios. With respect to the digital map, participants agreed that it was more useful than the paper map. However, participants did not strongly endorse the assertion that the digital map (compared to only radios) made them more aware of their situation. Soldiers agreed more that their command and control had improved with the radio comms alone compared to digital map alone. Considering the simultaneous use of radio and digital map, soldiers disagreed that they required less use of the radio communication system when they had the digital map. Further, the statement that all members needed a digital map was met with neutral ratings. Radios, therefore, seemed to be the more preferred technology.

Mission Capabilities: Soldiers were asked to rate the importance of the radio and digital map for specific mission capabilities where 1 represented "No Importance" and 7 represented "Extremely Important". Table 19 shows these results.

Table 19: Importance for specific mission capabilities

Mean(StDev)	Radio	Digital Map	Sig. Differences
Awareness of Friendly Forces	6.3 ± 0.6	6.5 ± 0.6	ns
Awareness of the Battle Situation	6.2 ± 0.8	5.4 ± 1.7	Radio > Digital Map
Coordination within the Section	6.2 ± 0.6	5.4 ± 1.2	Radio > Digital Map
Teamwork	5.7 ± 1.0	4.4 ± 1.5	Radio > Digital Map
Issuing / Receiving Orders	5.6 ± 1.5	4.7 ± 1.6	Radio > Digital Map
Passing Information	6.3 ± 0.9	4.4 ± 1.7	Radio > Digital Map
Requesting Information	6.3 ± 0.6	4.0 ± 1.8	Radio > Digital Map
Tempo of mission	5.3 ± 1.2	4.7 ± 1.6	Radio > Digital Map
Achieving mission timings	5.3 ± 1.3	5.5 ± 1.2	ns
Ability to maintain stealth	6.5 ± 0.8	4.1 ± 2.1	Radio > Digital Map
Ability to adapt to unexpected changes in mission	6.3 ± 0.7	5.4 ± 1.3	Radio > Digital Map
Minimizing casualties	5.7 ± 1.3	4.9 ± 1.5	Radio > Digital Map
Overall Mission Success	6.3 ± 0.7	5.4 ± 1.0	Radio > Digital Map

In general, having a radio was seen as being more important than having a digital map for most mission capabilities, including awareness 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 important, but not as important. As one participant confirmed, “radio, to me, is more important than the digital map”.

Mission Phases: Soldiers were asked to rate the importance of a radio and digital map for different phases of the mission where 1 represented “No Importance” and 7 represented “Extremely Important”. Table 20 shows the results.

Table 20: Importance for specific mission phases

Mean(StDev)	Radio	Digital Map	Sig. Differences
Pre-Mission Briefing	3.2 ± 1.8	4.3 ± 1.8	Digital Map > Radio
Advance to RV	5.9 ± 1.1	6.0 ± 0.8	ns
Approach Objective	6.2 ± 0.8	5.7 ± 1.5	Radio > Digital Map
Assault Objective	5.4 ± 1.7	3.3 ± 1.8	Radio > Digital Map
Consolidation	5.3 ± 1.6	3.7 ± 2.0	Radio > Digital Map

According to soldiers, digital maps have the most utility during the pre-mission briefing phase, presumably for planning and to be able to plot out mission routes. Radios and digital maps were seen as uniformly important while advancing to the RV. 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. One participant explained that the "radio plays an important role all the way through the mission", whereas the digital map "loses its importance after the RV in the assault of the objective".

4.5.4 Radio System Ratings and Comments

Finally, soldiers were asked to rate the acceptability of the radio equipment. The results are found in Table 21.

Table 21: Acceptability of radio equipment

Mean (StDev)	Acceptability rating
Radio	
Network Control Knob	4.8 ± 1.5
LED Display	4.8 ± 1.4
Volume Control Knob	5.8 ± 0.8
Size	5.0 ± 1.8
Method of Attaching to Webbing	3.3 ± 1.9
Weight	5.2 ± 1.7
Headset	
Fit	4.9 ± 1.7
Comfort	4.8 ± 1.7
Weight	6.3 ± 0.7
Cabling	4.1 ± 1.9
Sound Quality	6.0 ± 0.9
Detectability	5.9 ± 1.0
Push-to-talk	
Fit	5.5 ± 1.7
Comfort	5.6 ± 1.5
Ease of Operation	5.9 ± 1.5
Cabling	4.8 ± 1.7
Reliability	5.5 ± 1.5

For most items, the radio equipment was rated barely acceptable, with the exception of the method of attachment, which was rated unacceptable. The weight of the headset, its quality and detectability were rated reasonably acceptable. However, fit, comfort, and cabling were thought to be barely acceptable. The push-to-talk apparatus was thought to be between barely acceptable to reasonably acceptable.

Soldiers also had the opportunity to express their comments during the directed focus group. For the radio, they mentioned the following.

Likes

One soldier said that overall the radios "reduced stress, increased stealth and situational awareness as long as the troops remembered to use them during all phases", which would improve with "training". The radio contributed to the awareness of the "other" AG progress and status.

Radios maintained communication among the section members. As one soldier pointed out, "without comms…mistakes become more common because of miscommunication and your coordination with other AG is almost non-existent". It was reported that with hand signals "some guys give only part or the wrong message". Radios minimized this problem.

One soldier explained that the "movement during the approach and assault was greatly improved with the use of radios". The radio allowed for "spacing between soldiers" and "plans could be passed on without having to congregate the troops in one small area". Another soldier explained that with a radio, "instead of everyone having to pass the message down, it just had to be said once". Soldiers could also pass information to others without having to turn around. Soldiers could face "forward" even when they had to pass information to a comrade who was "held up in the background". However, it was suggested that, during an attack, yelling was more practical than pressing the comms button.

It was believed that a radio contributes to mission success.

Dislikes

As in the previous field study (Adams, Tack & Thomson, 2004), the "cabling" was a problem. Moreover, soldiers found switching networks to be a challenge. One soldier said that the radio is "excellent", but "sometimes there is too much information to be passed by different people at one time for the radio to be effective".

Though this could be an anomaly for one soldier, he mentioned that he did not like the time lapse from when the PTT switch was depressed to the time when a soldier could speak. He thought that was "unacceptable".

Radios were not always reliable. Sometimes they did not work. The message could get "cut off quite easily". One soldier said that he did not know when he was "being heard".

The headset was "uncomfortable after extended use" because of the "straps on [the] helmet".

Improvements

Some improvements that soldiers suggested were:

- The LED could go on top of the radio;
- Radios could have better range;
- SOPs needed to be developed for effective radio use.

4.5.5 Digital Map System Ratings and Comments

As Table 22 shows, the computer display for the digital map was rated unacceptable on a number of items.

Table 22: Acceptability of digital map computer display

Mean (StDev)	Acceptability rating
Computer Display	
Stylus	4.6 ± 1.7
LCD Display	5.1 ± 1.4
Size	1.8 ± 1.2
Method of Attaching to Forearm	2.4 ± 1.7
Weight	2.2 ± 1.1
Cabling	2.0 ± 1.2

Soldiers found the size, the method of attachment, the weight, and the cables all to be unacceptable. They did, however, rate the stylus and LCD display as acceptable.

For the digital map, soldiers mentioned the following.

Likes

The digital map was easy to use. The touch screen menus were easy to understand, i.e., the digital map was user friendly. It was easy to navigate and pass on information regarding the "plan". Some participants thought the digital map made following the route "easier". One reported that "less mental effort is required to navigate". One soldier said that "digital navigation is an excellent tool as long as it does not crash".

It was believed that the digital map added flexibility to a mission. One soldier commented that the route could be "immediately altered…with no real effect on time".

The digital map increased situation awareness. Soldiers were aware of the other AGs location: "You always knew exactly where you and everyone else were".

Dislikes

Soldiers mentioned the screen was problematic in a couple of ways. For example, the "touch screen" could be "unknowingly bumped, which would alter the display". Soldiers also believed that the screens could give away their position. The screen should be hidden at all angles except 90 degrees. Soldiers also had trouble seeing the screen in the daylight.

Orientation also seemed to be a challenge. A couple of participants said that sometimes the digital map was confusing because it always pointed to the north, forcing soldiers to turn in a direction that was consistent with that direction. Orienting the digital map to the ground all of the time was said to be confusing. One soldier reported that because of the "lack of scale" he was "unable to measure distance".

Some soldiers thought that the location for the digital map was not optimal. It was "way too big" and "frustrating to have on [the] wrist". One soldier commented that where the screen is located, it distracted people from the area of responsibility. Another thought that it might be "a distraction" in its current placement.

One soldier mentioned that the digital map was more precise than traditional map and compass, but it "loses importance at the assault". One reason for this is that the objective is usually in sight. However, it could be useful in "a two pronged assault".

One soldier said that the "AG is too small a group to take full advantage of a digital map".

Improvements

Participants provided suggestions to improve the digital map. These included the following.

- The screen needs to be robust, and there should be an option to cover it for protection and tactical reasons;
- The resolution could be improved on the map and more terrain features could be added;
- Dim the screen;
- Attach a cable to the pen so that it does not get lost;
- It needs to be smaller;
- Velcro is not a reliable attachment method because it gets weak with use and dirt;
- Add a scale for measurement;
- Have a lock out so only the SC and 2IC can add or delete certain information pertaining to route;
- It needs to have a built in compass;
- An arrow in the corner of the screen that pointed to the required direction.

4.6 Limitations

This study has several limitations. As with the previous study in the field (Adams, Tack & Thomson, 2004), the SIMLAS system failed to work adequately. As a result, there was no team performance data recorded. These challenges prevent us from identifying significant differences in communications and team performance and process measures across the four conditions.

The radio communication at times would not transmit as a result of the wooded area terrain. For example, participants trying to transmit from within a ditch or ravine would not always get a signal. Consequently, these communications were not recorded.

There were also substantial problems with the Xybernaut digital map system. In the early phases of the experiment, the system often over heated, causing the screen to freeze. In these cases, participants lost the ability to track themselves and their teammates. In such cases, participants would compensate by sharing systems that were operating. This slowed down their progress. Moreover, the wireless card often disconnected, causing the participant to lose their signal on the Xybernaut digital map. It is very possible that the practical difficulties encountered in completing this study may have resulted in unfair evaluation of the absolute value of digital mapping technology because of the poor performance of this new system. Further research with improved technology may help to provide a stronger test of the value of digital mapping capabilities.

5. Discussion

Overall, when investigating the type and function of voice communication within a dismounted infantry section engaged in an urban assault with or without a radio and/or digital map, the results showed very little difference across the four conditions (Digital/No Radio, Paper/No Radio, Digital/Radio, and Paper/Radio). Furthermore, the findings in the current study reflect, to a large degree, similar findings in the previous studies (Adams, Tack, & Sartori 2004a; Adams, Tack, & Thomson, 2004; Adams, Tack & Sartori, 2004b). 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. The failure to identify dramatic differences could be explained by a number of reasons.

For one, the experimental conditions with the digital map were less than optimal. System failure often prevented optimum use of the Xybernaut. As well, without prior experience and no SOP, soldiers may have had difficulty integrating both the Xybernaut and radio comms into their current practices. It would be worthwhile to conduct experiments with participants who had previous experience with the radios and digital map and also had entrenched SOPs for these technologies. Such studies might yield differences in the amount of communication as well as differences in the type and function of communication. For example, orders and transfers of location may be greatly reduced with greater digital map proficiency.

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. 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 be able to plot 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.

When thinking generally about the Xybernaut system, most soldiers thought that the current Xybernaut digital map was too big, and was a distraction in its location on the wrist. A smaller, more accessible digital map may be more appropriate for dismounted infantry assault teams. Further, the screen should be visible only at a 90 degree angle so that it does not give away the position of the user to the enemy. At present, the glare from the screen would act as a target to enemy forces.

Another challenge with the Xybernaut was orientation. It is automatically oriented towards the North. Consequently, soldiers had to stop, align the compass mounted on the top of the Xybernaut to North, locate their position, and then take a bearing. Compared to a paper map, this is efficient technology. However, it was also a source of confusion for some. A digital map that has an "egocentric" frame of reference might promote faster orientation times, and increase the tempo of the mission and mission timings. The value of the egocentric frame of reference is it represents

change as it would appear from the users' actual frame of reference. In other words, the map would correspond to the direction the user faced. This, of course, may be difficult to achieve given current software. Yet, there is value in pursuing research in this area.

Consistent with all of the previous studies investigating the use of radios in tactical assault missions, participants were overwhelmingly in support of radios. And looking closely at the pathways of communication, it shows that SC and 2IC favour speaking with each other while all of the other section members listen. Ultimately, communications may decrease when soldiers develop SOPs and integrate them into their current practices, passing information more thoroughly and expediently so that all section members can hear irrespective of their location.

As noted earlier, the practical difficulties encountered in completing this study may have resulted in unfair evaluation of the absolute value of digital mapping technology because of the poor performance of this new system. It will be important to explore the impact of providing digital map capability with a more ruggedized system in order to understand its true value.

6. References

A. ADAMS, B., TACK, D., and SARTORI, J. (2004a). Evaluation of Radio Communication in Dismounted Infantry Operations. Draft report submitted to Defence Research and Development Canada Toronto.

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ANNEX A

Situation Awareness

PARTICIPANT NUMBER : _____ SESSION NUMBER : _____

ASSAULT GROUP:_____ SECTION NUMBER: _____

CONDITION:

RADIO:	○ **RADIO**	○ **NO RADIO**	
MAP:	○ **DIGITAL MAP**	○ **PAPER MAP**	
ROLE:	○ **RIFLEMAN**	○ **2IC**	○ **SECTION COMD**

Answer the following questions by filling in the appropriate circle.

1. Indicate the status of **OTHER** Assault Group for the following factors.

Casualties:	None	One	Two	Three	Four
	○	○	○	○	○
RV Timing:	Very Early	Early	On-time	Delayed	Very Delayed
	○	○	○	○	○

2. Based on the mission status at this point, **PREDICT THE FUTURE OUTCOME** of the assault.

Assault Completion:	Very Early	Early	On-time	Delayed	Very Delayed
	○	○	○	○	○

Teamwork Questionnaire

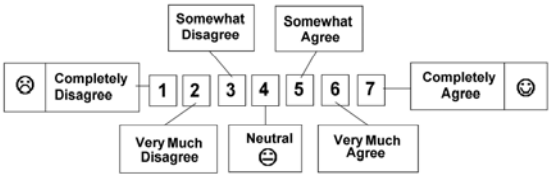
PARTICIPANT NUMBER : _____ SESSION NUMBER : _____

ASSAULT GROUP:_____ SECTION NUMBER: _____

CONDITION:

RADIO:	○ **RADIO**	○ **NO RADIO**	
MAP:	○ **DIGITAL MAP**	○ **PAPER MAP**	
ROLE:	○ **RIFLEMAN**	○ **2IC**	○ **SECTION COMD**

USING THE SCALE PROVIDED, INDICATE THE EXTENT TO WHICH YOU AGREE WITH THE FOLLOWING STATEMENTS WITH RESPECT TO YOUR CURRENT TEAM.



	☹			😐			☺
	1	**2**	**3**	**4**	**5**	**6**	**7**
1. I have faith in the ability of my team.	○	○	○	○	○	○	○
2. My team protects each other in risky situations.	○	○	○	○	○	○	○
3. Even when things are risky, my team puts our words into action.	○	○	○	○	○	○	○
4. I am confident that I can predict what my teammates are likely to do.	○	○	○	○	○	○	○
5. My team has a common understanding of what to do in high risk situations.	○	○	○	○	○	○	○
6. The communication in my team is effective.	○	○	○	○	○	○	○
7. I have confidence in the members of my team	○	○	○	○	○	○	○

NASA TLX Questionnaire

PARTICIPANT NUMBER : _____ SESSION NUMBER : _____

ASSAULT GROUP : _____ _____SECTION NUMBER : _____

RADIO CONDITION: **RADIO** **NO RADIO**

○ ○

MAP CONDITION: **DIGITAL MAP** **PAPER MAP**

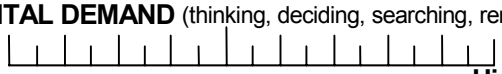
○ ○

ROLE: **RIFLEMAN** **2IC** **SECTION COMD**

○ ○ ○

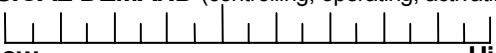
Rate the trial by marking each scale at the point which matches your experience. Each line has two endpoint descriptors to help describe the scale. Please consider your responses to these scales carefully.

MENTAL DEMAND (thinking, deciding, searching, remembering)



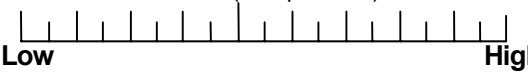
Low (easy, simple) **High** (demanding, complex)

PHYSICAL DEMAND (controlling, operating, activating)



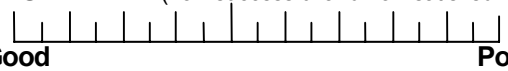
Low (easy, restful) **High** (demanding, laborious)

TEMPORAL DEMAND (time pressure)



Low (leisurely) **High** (frantic)

PERFORMANCE (how successful and how satisfied were you with performing this task?)

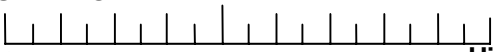


Good **Poor**

EFFORT (how hard did you have to work, both mentally and physically?)

Low **High**

FRUSTRATION



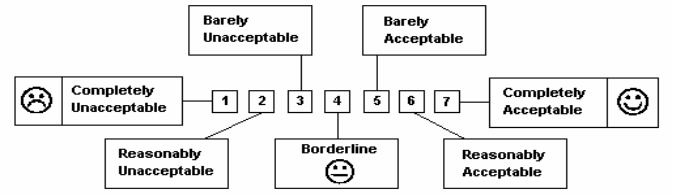
Low (gratified, complacent) **High** (discouraged, annoyed)

Exit Questionnaire

PARTICIPANT NUMBER : _____ SESSION NUMBER : _____

ASSAULT GROUP:_____ SECTION NUMBER: _____

1. USING THE SCALE PROVIDED, INDICATE THE ACCEPTABILITY OF THE FOLLOWING FEATURES FOR THE NO RADIO AND RADIO COMMUNICATION METHODS.



	No Radio	Radio Communications
INFORMATION TRANSFER	☹ 1 2 3 4 5 6 7 ☺	☹ 1 2 3 4 5 6 7 ☺
Amount of information that can be passed	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
Time required to pass information	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
Timeliness for initiating comms	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
Ease of passing information	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
Ease of requesting information	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
Ease of receiving information	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
Ease of getting acknowledgement of information received	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
Ease of getting acknowledgement of information understood	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
Accuracy of information passed	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
Message detail possible	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○

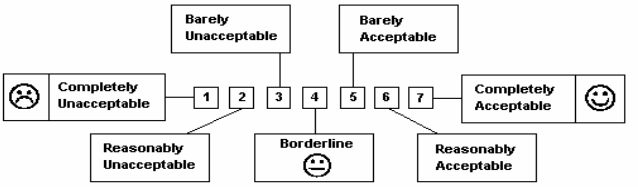
WITHIN ASSAULT GROUP	☹ 1 2 3	😐 4 5 6	☺ 7	☹ 1 2 3	😐 4 5 6	☺ 7
Coordination of movement	○ ○ ○	○ ○ ○	○	○ ○ ○	○ ○ ○	○
Coordination of fire	○ ○ ○	○ ○ ○	○	○ ○ ○	○ ○ ○	○
Coordination of action	○ ○ ○	○ ○ ○	○	○ ○ ○	○ ○ ○	○
Issuing / receiving orders	○ ○ ○	○ ○ ○	○	○ ○ ○	○ ○ ○	○
Designating targets	○ ○ ○	○ ○ ○	○	○ ○ ○	○ ○ ○	○
Ease of distributing message within Assault Group	○ ○ ○	○ ○ ○	○	○ ○ ○	○ ○ ○	○
Awareness of location of your Assault Group members	○ ○ ○	○ ○ ○	○	○ ○ ○	○ ○ ○	○
Awareness of casualties among your Assault Group members	○ ○ ○	○ ○ ○	○	○ ○ ○	○ ○ ○	○
Awareness of ammunition usage of your Assault Group	○ ○ ○	○ ○ ○	○	○ ○ ○	○ ○ ○	○

BETWEEN ASSAULT GROUP	☹ 1 2 3	😐 4 5 6	☺ 7	☹ 1 2 3	😐 4 5 6	☺ 7
Coordination of Assault Group movement	○ ○ ○	○ ○ ○	○	○ ○ ○	○ ○ ○	○
Coordination of Section fire	○ ○ ○	○ ○ ○	○	○ ○ ○	○ ○ ○	○
Coordination of Section action	○ ○ ○	○ ○ ○	○	○ ○ ○	○ ○ ○	○
Issuing / receiving orders	○ ○ ○	○ ○ ○	○	○ ○ ○	○ ○ ○	○
Designating targets	○ ○ ○	○ ○ ○	○	○ ○ ○	○ ○ ○	○
Ease of distributing message within Section	○ ○ ○	○ ○ ○	○	○ ○ ○	○ ○ ○	○
Awareness of location of the other Assault Group	○ ○ ○	○ ○ ○	○	○ ○ ○	○ ○ ○	○
Awareness of casualties of the other Assault Group	○ ○ ○	○ ○ ○	○	○ ○ ○	○ ○ ○	○
Awareness of ammunition usage of the other Assault Group	○ ○ ○	○ ○ ○	○	○ ○ ○	○ ○ ○	○
OVERALL ACCEPTANCE	○ ○ ○	○ ○ ○	○	○ ○ ○	○ ○ ○	○

Likes Dislikes

Indicate the features you liked the most about the Radio.	Indicate the features you liked the least about the Radio.
Improvements How would you improve the radio communications system?	

2. USING THE SCALE PROVIDED, INDICATE THE ACCEPTABILITY OF THE FOLLOWING FEATURES FOR THE DIGITAL MAP METHOD AND THE PAPER MAP METHOD.



	Paper Map	Digital Map
LOCATION AWARENESS	☹ 1 2 3 ☺ 4 5 6 7	☹ 1 2 3 ☺ 4 5 6 7
Awareness of own location	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
Awareness of location of your Assault Group members	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
Awareness of location of the other Assault Group	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
ASSAULT GROUP COORDINATION	☹ 1 2 3 ☺ 4 5 6 7	☹ 1 2 3 ☺ 4 5 6 7
Coordination of movement	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
Coordination of fire	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
Coordination of action	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
Issuing / receiving orders	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
Designating targets	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
Sharing information	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
SECTION COORDINATION	☹ 1 2 3 ☺ 4 5 6 7	☹ 1 2 3 ☺ 4 5 6 7
Coordination of Section movement	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
Coordination of Section fire	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
Coordination of Section actions	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
Sharing information	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
Ability to maintain mission tempo	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
Ability to meet mission timings	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
Anticipating the action of the other Assault Group	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○
OVERALL ACCEPTANCE	○ ○ ○ ○ ○ ○ ○	○ ○ ○ ○ ○ ○ ○

Likes Dislikes

Indicate the features you liked the most about the digital map.	Indicate the features you liked the least about the digital map.
Improvements How would you improve the digital map system?	

3. READ THE FOLLOWING STATEMENTS AND INDICATED WHETHER YOU AGREE OR DISAGREE BY USING THE SCALE PROVIDED.

	Strongly Disagree			Neutral			Strongly Agree
	1	2	3	4	5	6	7
We were more effective as a team with the radio communication system than with the no radio system.	○	○	○	○	○	○	○
All members of a dismounted infantry Section should be provided with radio comms during a mission.	○	○	○	○	○	○	○
We were more aware of our situation with the no radio system than with the radio comms system.	○	○	○	○	○	○	○
Assault Group command and control were improved with the radio comms system, over the no radio system.	○	○	○	○	○	○	○
Section command and control were improved with the no radio system, over the radio comms system.	○	○	○	○	○	○	○
The digital map was more useful than the paper map.	○	○	○	○	○	○	○

	Strongly Disagree			Neutral			Strongly Agree
	1	2	3	4	5	6	7
We were more aware of our situation with the digital map system alone than with the radio comms system alone.	○	○	○	○	○	○	○
Assault Group command and control were improved with the digital map alone, over the radio comms system alone.	○	○	○	○	○	○	○
Section command and control were improved with the radio comms system alone, over the map system alone.	○	○	○	○	○	○	○
With a digital map system, we did not need to use the radio comms system as often.	○	○	○	○	○	○	○
All members of a dismounted infantry Section should be provided with a digital map during a mission.	○	○	○	○	○	○	○
All members of a Section should be provided with **both** a radio and a digital map during a mission.	○	○	○	○	○	○	○

Comments

4. RATE THE IMPORTANCE OF A RADIO FOR EACH PHASE OF THE MISSION.

Mission Phases	***Importance Rating Scale***						
	No Importance	Slight Importance	Little Importance	Some Importance	Moderately Important	Very Important	Extremely Important
Pre-Mission Briefing	○	○	○	○	○	○	○
Advance to RV	○	○	○	○	○	○	○
Approach Objective	○	○	○	○	○	○	○
Assault Objective	○	○	○	○	○	○	○
Consolidation	○	○	○	○	○	○	○

5. RATE THE IMPORTANCE OF A DIGITAL MAP FOR EACH PHASE OF THE MISSION.

Mission Phases	***Importance Rating Scale***						
	No Importance	Slight Importance	Little Importance	Some Importance	Moderately Important	Very Important	Extremely Important
Pre-Mission Briefing	○	○	○	○	○	○	○
Advance to RV	○	○	○	○	○	○	○
Approach Objective	○	○	○	○	○	○	○
Assault Objective	○	○	○	○	○	○	○
Consolidation	○	○	○	○	○	○	○

Comments

6. RATE THE IMPORTANCE OF A RADIO FOR THESE FEATURES.

Mission Phases	***Importance Rating Scale***						
	No Importance	**Slight Importance**	**Little Importance**	**Some Importance**	**Moderately Important**	**Very Important**	**Extremely Important**
Awareness of Friendly Forces	○	○	○	○	○	○	○
Awareness of the Battle Situation	○	○	○	○	○	○	○
Coordination within the Section	○	○	○	○	○	○	○
Teamwork	○	○	○	○	○	○	○
Issuing / Receiving Orders	○	○	○	○	○	○	○
Passing Information	○	○	○	○	○	○	○
Requesting Information	○	○	○	○	○	○	○
Tempo of mission	○	○	○	○	○	○	○
Achieving mission timings	○	○	○	○	○	○	○
Ability to maintain stealth	○	○	○	○	○	○	○
Ability to adapt to unexpected changes in mission	○	○	○	○	○	○	○
Minimizing casualties	○	○	○	○	○	○	○
Overall Mission Success	○	○	○	○	○	○	○

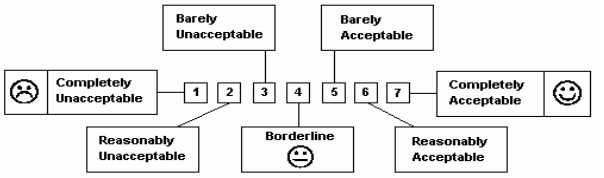
Comments

7. RATE THE IMPORTANCE OF A DIGITAL MAP FOR THESE FEATURES.

Mission Phases	***Importance Rating Scale***						
	No Importance		**Little Importance**		**Moderately Important**		**Extremely Important**
		Slight Importance		**Some Importance**		**Very Important**	
Awareness of Friendly Forces	○	○	○	○	○	○	○
Awareness of the Battle Situation	○	○	○	○	○	○	○
Coordination within the Section	○	○	○	○	○	○	○
Teamwork	○	○	○	○	○	○	○
Issuing / Receiving Orders	○	○	○	○	○	○	○
Passing Information	○	○	○	○	○	○	○
Requesting Information	○	○	○	○	○	○	○
Tempo of mission	○	○	○	○	○	○	○
Achieving mission timings	○	○	○	○	○	○	○
Ability to maintain stealth	○	○	○	○	○	○	○
Ability to adapt to unexpected changes in mission	○	○	○	○	○	○	○
Minimizing casualties	○	○	○	○	○	○	○
Overall Mission Success	○	○	○	○	○	○	○

Comments

8. USING THE SCALE PROVIDED, INDICATE THE ACCEPTABILITY OF THE FOLLOWING FEATURES FOR THE RADIO EQUIPMENT USED IN THIS TRIAL.



	1 Acceptability						
RADIO	☹ 1	2	3	😐 4	5	6	☺ 7
Network Control Knob	○	○	○	○	○	○	○
LED Display	○	○	○	○	○	○	○
Volume Control Knob	○	○	○	○	○	○	○
Size	○	○	○	○	○	○	○
Method of Attaching to Webbing	○	○	○	○	○	○	○
Weight	○	○	○	○	○	○	○
HEADSET	☹ 1	2	3	😐 4	5	6	☺ 7
Fit	○	○	○	○	○	○	○
Comfort	○	○	○	○	○	○	○
Weight	○	○	○	○	○	○	○
Cabling	○	○	○	○	○	○	○
Sound Quality	○	○	○	○	○	○	○
Detectability	○	○	○	○	○	○	○
PUSH-TO-TALK	☹ 1	2	3	😐 4	5	6	☺ 7
Fit	○	○	○	○	○	○	○
Comfort	○	○	○	○	○	○	○
Ease of Operation	○	○	○	○	○	○	○
Cabling	○	○	○	○	○	○	○
Reliability	○	○	○	○	○	○	○

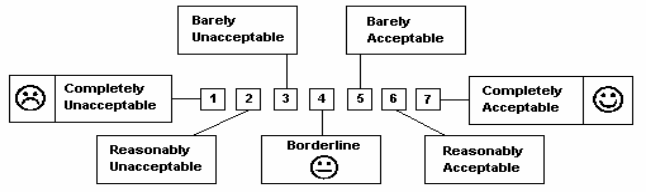
Likes Dislikes

Indicate the features you liked the most about the Radio.	Indicate the features you liked the least about the Radio.

Improvements

How would you improve the radio equipment?

9. USING THE SCALE PROVIDED, INDICATE THE ACCEPTABILITY OF THE FOLLOWING FEATURES FOR THE COMPUTER TABLET USED IN THIS TRIAL.



	Acceptability
COMPUTER DISPLAY	☹ 😐 ☺ **1 2 3 4 5 6 7**
Stylus	○ ○ ○ ○ ○ ○ ○
LED Display	○ ○ ○ ○ ○ ○ ○
Size	○ ○ ○ ○ ○ ○ ○
Method of Attaching to Forearm	○ ○ ○ ○ ○ ○ ○
Weight	○ ○ ○ ○ ○ ○ ○
Cabling	○ ○ ○ ○ ○ ○ ○

Likes Dislikes

Indicate the features you liked the most about the computer tablet.	Indicate the features you liked the least about the computer tablet.

Improvements

How would you improve the computer tablet?

The frequency of communications in the "Other" category

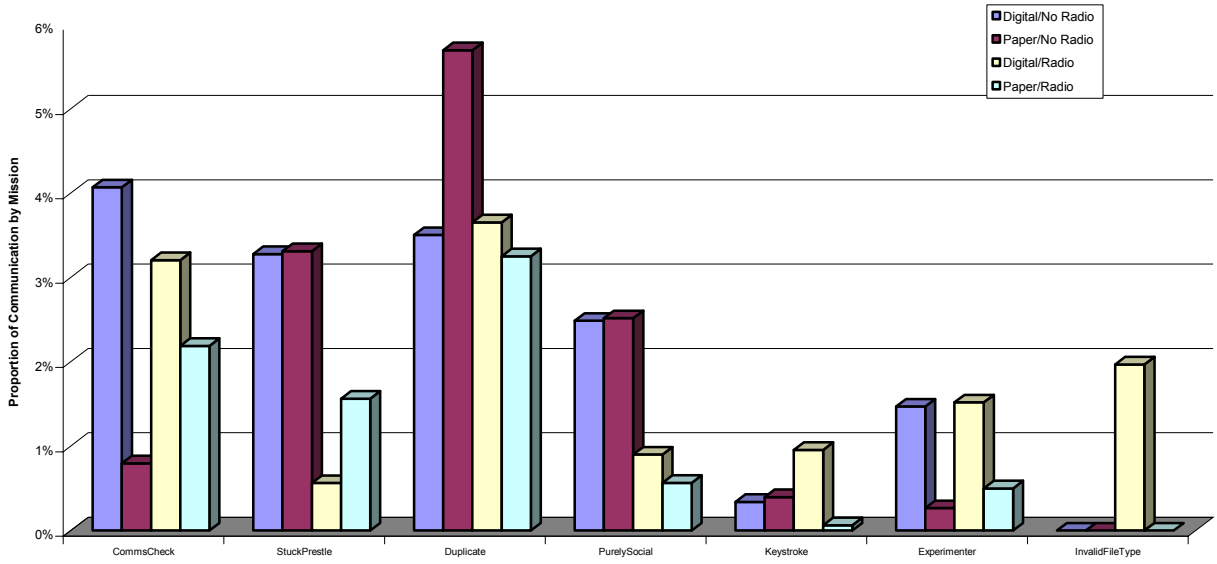


Figure A1: The frequency of communications in the "other" category

UNCLASSIFIED

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(Security classification of the title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (The name and address of the organization preparing the document, Organizations for whom the document was prepared, e.g. Centre sponsoring a contractor's document, or tasking agency, are entered in section 8.)

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3. TITLE (The complete document title as indicated on the title page. Its classification is indicated by the appropriate abbreviation (S, C, R, or U) in parenthesis at the end of the title)

Field Evaluation of Digital Maps and Radio Communication in Dismounted Infantry Operations (U)
Évaluation des cartes numériques et des communications radio dans le cadre des opérations de l'infanterie débarquée, en conditions opérationnelles

4. AUTHORS (First name, middle initial and last name. If military, show rank, e.g. Maj. John E. Doe.)

Barbara D. Adams; David W. Tack; Michael H. Thomson

5. DATE OF PUBLICATION (Month and year of publication of document.)	6a NO. OF PAGES (Total containing information, including Annexes, Appendices, etc.)	6b. NO. OF REFS (Total cited in document.)
October 2005	75	4

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(U) As part of the Soldier Information Requirements Technology Demonstration (SIREQ−TD) project, this study examined the impact of providing both digital mapping and radio communication to dismounted infantry teams performing tactical assault missions in a wooded environment.

A nineteen−day field trial was conducted in a wooded area in Ft. Benning, Georgia, over the periods 29 October – 14 November, 2002, and 2 March – 3 March, 2003. Thirty−two Canadian regular force infantry soldiers performed force−on−force tactical assault missions in wooded terrain. Each soldier participated in all four research conditions, which included a paper map and no radio (Paper/No Radio), a paper map and a radio (Paper/Radio), a digital map and no radio (Digital/No Radio), and a digital map and a radio (Digital/Radio). For any one mission, eight soldiers worked together as an organic infantry section, comprised of two Assault Groups (AGs), to engage an enemy force of four soldiers occupying a defensive position in the wooded area.

The study showed that although the type and function of communication did not change dramatically with and without a digital map and radio, there was an increased amount of overall communication when soldiers carried radios compared to when they did not. Results also showed that there were some differences in team processes. More specifically, participants felt they had a better awareness of casualties with a paper map than with a digital map. Participants did rate perceived workload significantly lower with a digital map, regardless of whether they had a radio or not, but there were no perceived differences in teamwork.

In both exit questionnaires and focus groups, participants were highly in favour of having a digital map and radio communications. Radios were seen to significantly enhance information transfer, as well as coordination within and between AGs. Digital maps were rated as significantly enhancing location awareness, as well as coordination within and between AGs. Both digital maps and radios were rated as significantly more acceptable than the current in−service alternatives. In general, however, 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 as 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 for being able to plot 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.

Limitations of the current study are discussed. The primary limitation relates to the serious technical difficulties encountered while conducting this study, as the digital mapping systems did not perform very well. As such, the true value of digital mapping may have been underestimated by participants. Implications for future research regarding the digital map are discussed.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

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Soldier Information Requirements Technology Demonstration Project; SIREQ TD; digital map; situation awareness; mission planning; decision making; information transfer

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