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EVALUATION OF RADIO COMMUNICATION IN DISMOUNTED INFANTRY SECTIONS

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Abstract

SIREQ-TD (Soldier Information Requirements Technology Demonstrator) has determined that information transfer and communication between members in a dismounted infantry section is critical for mission success, and most soldier modernization programs have adopted an intra-section radio as part of their standard equipment. The purpose of this pilot study was to determine whether the addition of a radio would improve the communication and performance of an 8-soldier section in a computer-simulated 1st person shooter game. Specifically, we were interested in determining which aspects of communication and performance would or would not be enhanced, which radio network configurations were best, and whether there were differences in information exchanged with a radio and without.

Thirty-two (32) reserve force infantry soldiers participated in 27 virtual-reality multi-player missions, while seated at computer workstations in a laboratory over the course of 8 days, to evaluate the effects of adding a radio communications network to simulated dismounted infantry operations. In the No Radio condition, soldiers were required to whisper and use hand signals to communicate. In the Radio conditions, four networks were configured to control which section members could speak to each other. All communications were recorded and later content analyzed for type, function, references to friendlies vs. enemies, duration, pathways (role and network), and anticipation ratios. Outcome measures related to team performance (ammunition use, rounds taken and AG deaths) and team process (status awareness, teamwork, and workload) were also taken throughout the study. In addition, exit questionnaires and focus groups also explored participants' experience with and perceived benefits of radio communications.

Results indicated that although there was considerably more communication with a radio than without (i.e. a ratio of nearly 10 to 1), there was, in general, a very similar pattern of communication between conditions. For example, orders were the most common type of communication followed by information transfers both with a radio and without. However, there were twice as many orders (such as an order for location) in the No Radio condition compared to the Radio condition. The type of communication was somewhat more differentiated when soldiers had a radio. There were also similar patterns across conditions in the function of communication. In both conditions, the primary function of communication was related to location, followed by status. However, in the Radio condition, there were fewer communications related to location and more related to status compared to the No Radio condition. In both conditions, the Section Commanders (SC's) and second-in-command (2IC's) generated the most communication. Assault group members communicated twice as much when they had a radio compared to when they did not. In terms of network configuration, the most traffic was generated by the four-person assault group networks, followed by the leader net, and then the 8-person network.

Although results from the mission performance data (rounds taken, fired and AG deaths) showed no difference between missions with a radio and without, perceived workload was significantly higher with a radio than without. This, however, might be a consequence of the sheer volume of radio activity and the undefined radio SOP.

Exit questionnaires and focus groups explored soldiers' perception of the radio communication system, and the relative advantages and disadvantages of having this kind of communication during infantry operations. In spite of the lack of quantitative data supporting improvements in performance from the presence of a radio, the focus group discussion at the end of the study indicated overwhelming support for the addition of a radio, and information transfer and coordination both within and between AG was rated as more acceptable with a radio than without. Limitations and implications for future research are discussed.

Résumé

La démonstration des technologies relatives aux besoins des soldats en matière d'information (SIREQ TD) a permis de déterminer que les échanges d'information et les communications entre les membres d'une section d'infanterie à pied sont critiques pour le succès de la mission, au point que la plupart des programmes de modernisation de l'équipement du fantassin incluent dans leur équipement standard des liaisons radio intra-section. L'objet de la présente étude pilote était de déterminer dans quelle mesure la disponibilité de ces liaisons radio améliorerait les communications et le rendement d'une section de 8 fantassins participant à un jeu de guerre personnel en simulation informatique. Nous cherchions plus précisément à déterminer quels aspects de la communication et du rendement seraient ou ne seraient pas améliorés, quelles configurations de réseau radio offriraient les meilleures possibilités, et si la disponibilité de la radio allait créer des différences significatives dans les échanges d'information.

Trente-deux (32) fantassins de la Réserve ont participé sur une période de 8 jours à 27 missions multi-joueurs en réalité virtuelle devant des ordinateurs installés en laboratoire, dans le but d'évaluer les effets de l'introduction d'un réseau de communications radio dans des opérations d'infanterie simulées. Dans les simulations sans radio, les fantassins devaient chuchoter et communiquer par des signaux à main. Dans les simulations avec radio, quatre configurations de réseau entre certains membres de la section ont été testées. Toutes les communications étaient enregistrées et leur contenu ultérieurement analysé par type, fonction, références à des amis ou à des ennemis, durée, parcours (rôle et réseau) et rapports d'anticipation. Tout au long de l'étude, les mesures de résultats ont porté sur le rendement de l'équipe (coups tirés, coups reçus et pertes au sein du GA) et les processus d'équipe (connaissance de la situation, travail d'équipe et charge de travail). En fin de période, des questionnaires et des groupes de discussion ont permis de recueillir les expériences des participants et les avantages perçus des liaisons radio.

Les résultats indiquent que la disponibilité de liaisons radio s'est traduite par une augmentation considérable du nombre de communications (dans un rapport de près de 10 à 1), mais avec peu d'effet sur les schémas de communication. Par exemple, les types de communication les plus courants étaient les ordres, suivis des transferts d'information, avec ou sans radio. Cependant, les ordres étaient deux fois plus nombreux (notamment les ordres de position) sans la radio. Les types de communications étaient sensiblement plus variés pour les soldats disposant d'une radio. La fonction de communication suivait des modèles similaires avec et sans radio. Dans les deux cas, la fonction première de la communication était la désignation de position (endroit), suivie de la situation. Cependant, avec la radio, il y avait moins d'échanges de position et plus de situation. Dans un cas comme dans l'autre, le chef de section et son adjoint étaient à l'origine de la plupart des communications. Les membres des groupes d'assaut communiquaient deux fois plus quand ils disposaient d'une radio que quand ils n'en avaient pas. Sur le plan de la configuration du réseau, la majorité du trafic radio provenait des réseaux des groupes d'assaut de 4 personnes, suivis par le réseau de commandement, et enfin par le réseau de 8 personnes.

Bien que les résultats en termes de rendement dans la mission (coups reçus, coups tirés et pertes au sein du GA) ne fassent pas ressortir de différences entre les missions avec et sans radio, la charge de travail perçue était sensiblement plus importante avec la radio. Il est cependant possible que ce soit une conséquence du volume de trafic radio et de l'absence de procédures radio clairement établies.

Les questionnaires finaux et les groupes de discussion ont permis d'explorer la perception que les soldats avaient de leur système de communication radio et de ses avantages et inconvénients relatifs dans le cadre des opérations d'infanterie. En dépit d'un manque de données quantitatives à l'appui des gains de rendement associés à la disponibilité de liaisons radio, les discussions de groupe en fin d'étude ont permis de faire ressortir un appui écrasant en faveur de l'ajout de la radio; les transferts et la coordination de l'information à l'intérieur d'un GA et entre des GA ont été qualifiés de plus efficaces avec la radio que sans. Les limitations de l'analyse et les implications pour la recherche future sont en cours de discussion.

Executive Summary

This study is the first in a series explaining the impact of radio communication on small infantry teams for the Soldier Information Requirements Technology Demonstrator (SIREQ-TD). The SIREQ cognitive task analyses identified the transfer of information and communication between members in a dismounted infantry section as critical requirements for mission success. In the case of a typical execution phase of any mission, soldiers currently whisper or use hand signals during stealthy actions or use louder voices during engagements. Both methods have obvious shortcomings including the necessity of a clear a line of sight for hand signals, and the risk of a spoken message being unheard in noisy battle conditions. To overcome these current deficiencies in intra-section communications, most soldier modernization programmes have adopted an intra-section radio as part of their hardware ensemble.

The main purpose of the current study was to determine the effects of adding a radio to intra-section communication. Some possible advantages of a radio might include increased individual and/or collective status awareness, reduced individual mental workload, and improved team coordination and execution. Another purpose of the current study was to determine the most effective communications network configuration (i.e. who in the section should get a radio?). Four radio network configurations were used in this study:

- Network #1 = Sect. Comd. and 2IC only;
- Network #2 = Sect. Comd. Assault Group members only (i.e. four soldiers);
- Network #3 = 2IC Assault Group members only (i.e. four soldiers); and
- Network #4 = All Section members (i.e. all eight soldiers).

We were interested not only in which networks were used most often, but the types of information that were transferred over the various networks. This analysis would provide a better understanding of the information exchange requirements within a section for a given mission, and would further highlight the deficiencies with the current in-service intra-section capability.

In this exploratory investigation into intra-section communications, the following aims were pursued:

- To investigate the pathways, types, and functions of radio communications within a dismounted infantry section.
- To compare communications traffic across four network configurations (defined above).
- To compare the levels of team performance (rounds fired and taken and AG deaths) and team process (status awareness, teamwork, workload) on missions with a radio communications network and missions without radio communication.
- To gather feedback from soldiers concerning their opinions on the advantages and disadvantages of the Radio versus No Radio conditions with respect to hardware, network configurations, and perceived impact on team process and performance.

An eight-day laboratory experiment was undertaken at the Defence Research and Development Canada (DRDC) over the period of 17 – 26 September 2001. Twelve (n = 12) reserve force infantry soldiers were configured into three 8-man teams, and participated in 27 virtual-reality

multi-player missions, while seated at a computer workstation, to evaluate the effects of adding a radio communications network to dismounted infantry operations. Approximately half of the missions included the use of a radio voice communications network while the communication in the other half paralleled that of regular infantry operations which do not use radios. For any one mission, eight soldiers worked together as an organic infantry section comprised of two assault groups, and engaged human enemy in the pursuit of a goal-based mission in a highly realistic, virtual urban environment. Human factors (HF) measures included mission outcome, status awareness, workload, communication measures, and teamwork factors. Data collection included performance measures, questionnaires, and focus groups.

Results of the content analysis showed that despite differences in the frequency of communication, the pattern of communication in the Radio and No Radio conditions was relatively similar. For example, orders were the most common type of communication followed by transfers of information both with a radio and without. However, there were twice as many orders (such as an order for location) in the No Radio condition compared to the Radio condition. The type of communication was also somewhat more differentiated when soldiers had a radio. There were also similar patterns across conditions in the functions of communication. In both conditions, the primary function of communication was related to location, followed by status. However, in the Radio condition, there were fewer communications related to location and more related to status compared to the No Radio condition. There was no difference in the duration of messages between the Radio and No Radio conditions, but information was slightly more elaborated in the former.

In both conditions, the Section Commanders (SC's) and second-in-command (2IC's) generated the most communication. However, communication was more evenly distributed over roles when soldiers had a radio. Indeed, assault group members communicated approximately twice as often in the Radio condition than the No Radio condition. In general, SC's most common type of communication in both conditions was the order, followed by transfers. Interestingly, SC's included requests in their communications in the Radio condition where they did not in the No Radio condition. A similar pattern held for the 2IC's. With respect to assault group members, however, the Radio condition showed a large decrease in orders and an increase in both requests and acknowledgements. Transfers of information, on the other hand, remained consistently high in both conditions for assault group members.

Results also indicated that when sections had radios, the most traffic was generated by the four-person assault group networks, followed by the leader net, and then the 8-person network. This suggests a tendency to work at the assault group level, and for AG leaders to work on their exclusive net to coordinate the actions of their specific AG's, then disseminating this information to their assault group members. Not surprisingly, in the leader net, the SC's generated more orders and less transfers and acknowledgements than the 2IC's.

Although team process and performance results did not indicate an obvious benefit to radio communication, radios did seem to impose increased workload demand. This might have been a result of the sheer volume of radio activity and undefined radio SOP. Though soldiers reported few problems learning to use the radio system, they did have problems coordinating the computer avatar (which required having one's hands on the keyboard) while attempting to reach the intercom button in order to initiate communication.

Exit focus groups and questionnaires indicated overwhelming support for the addition of a radio, and information transfer and coordination both within and between AG was rated as more

acceptable with a radio than without. However, many soldiers also mentioned caveats concerning the use of comms. These included problems with busy signals, the concern that there would be too many mouths talking and giving opinions, and a serious concern that it may create a security blanket that soldiers might come to rely too heavily on, resulting in laziness or carelessness. Some soldiers also expressed concern that comms might represent a security threat in that the enemy might be able to intercept messages or listen in. This suggests that security encryption issues might be necessary to explore in future studies. In addition, a few soldiers indicated that they preferred hand signals because the SC was clearly in control in this condition and this is how it should be.

Soldiers also discussed the network configurations they thought would be best. Several soldiers thought that only the SC and 2IC should have radios, because that way the airwave was almost guaranteed to be clear. One solution to the problem with jammed comms from multiple speakers was an override switch for the SC and 2IC. As such, they could break in when they wanted. It was also frequently noted that the utility of a radio seemed to depend on whether or not the section was physically separated; most soldiers thought the comms worked better than hand signals when the team was split, but that they were unnecessary when the team stayed together.

Implications for future research and limitations of the present study are discussed.

Sommaire

Cette étude est la première d'une série visant à déterminer l'impact des communications radio sur de petites équipes d'infanterie, dans le cadre de la démonstration des technologies relatives aux besoins des soldats en matière d'information (SIREQ-TD). Les analyses de tâches cognitives SIREQ ont identifié les transferts d'information et les communications entre les membres d'une section d'infanterie à pied comme des facteurs critiques pour le succès de la mission. Dans la phase d'exécution traditionnelle d'une mission quelconque, les soldats communiquent à voix basse ou par des signaux à main au cours des actions discrètes, et à voix haute ou en criant au cours des engagements. Ces deux méthodes ont des inconvénients évidents, comme la nécessité d'être en vision directe pour les signaux à main et le risque qu'un message vocal ne soit pas compris dans le bruit du combat. Pour résoudre ces déficiences dans les communications au sein de la section, la plupart des programmes de modernisation de l'équipement ont adopté une radio intra-section dans la liste du matériel du fantassin.

Le but général de la présente étude était de déterminer les effets des liaisons radio sur les communications au sein de la section. Certains des avantages prévisibles étaient l'amélioration de la conscience individuelle et collective de la situation, une réduction de la charge de travail mental individuel, et une meilleure coordination et exécution des manœuvres d'équipe. Un autre but de l'étude était de déterminer quelle configuration de réseau serait la meilleure sur le plan de l'efficacité de la communication (autrement dit, qui a besoin d'avoir une radio dans la section). À cet effet, quatre configurations de réseau ont été étudiées.

- Réseau n° 1 = Chef de section (Cmdt) et son adjoint (CmdtA) seulement.
- Réseau n° 2 = Membres du groupe d'assaut du Cmdt (quatre soldats).
- Réseau n° 3 = Membres du groupe d'assaut du CmdtA (quatre soldats).
- Réseau n° 4 = Tous les membres de la section (huit soldats).

Nous étions intéressés, non seulement à déterminer quel réseau était le plus utile, mais aussi les types d'information échangés sur les divers réseaux. Cette analyse offrirait une meilleure compréhension des besoins d'échange d'information au sein d'une section, pour une mission donnée, et ferait mieux ressortir les déficiences des modes de communication actuels.

Les objectifs spécifiques de cette enquête exploratoire sur les communications intra-section étaient donc les suivants :

- étudier les cheminements, les types et les fonctions des communications radio au sein d'une section d'infanterie à pied;
- comparer les trafics des quatre configurations de réseau (définies ci-dessus);
- comparer les niveaux de rendement d'équipe (coups tirés et reçus, pertes du GA) et les processus d'équipe (conscience de la situation, travail d'équipe, charge de travail) au cours de missions conduites avec et sans un réseau de communications radio;
- recueillir les avis des participants sur les avantages et les inconvénients de la radio sur les plans du matériel, des configurations de réseau et des impacts perçus sur le rendement et les processus de l'équipe.

Recherche et développement pour la défense Canada (RDDC) a donc procédé à des expériences en laboratoire sur une période de huit jours, du 17 au 26 septembre 2001. Douze (n = 12) fantassins de la Réserve étaient configurés en trois équipes de 8 participants à 27 missions multi-joueurs en réalité virtuelle devant des ordinateurs, afin d'évaluer les effets de l'ajout d'un réseau de communications radio sur les opérations d'une section d'infanterie à pied. Environ la moitié de ces missions utilisaient un réseau de communication radio vocale, alors que l'autre moitié se déroulait sans radios, selon les techniques traditionnelles de l'infanterie. Pour chaque mission, les huit participants formaient une section d'infanterie organique divisée en deux groupes d'assaut et engagée dans des combats urbains avec une mission basée sur des objectifs, dans un environnement virtuel hautement réaliste. Les facteurs humains (FH) observés comprenaient l'issue de la mission, la connaissance de la situation, la charge de travail, le trafic de communication et les aspects relatifs au travail d'équipe. La collecte des données était basée sur des mesures de rendement, des questionnaires et des groupes de discussion.

L'analyse des contenus des communications a révélé qu'en dépit de différences de fréquences des messages, les schémas restaient relativement similaires, avec ou sans radio. Par exemple, dans les deux cas de figure, les ordres représentaient le type de communication le plus fréquent, suivi des transferts d'information. Cependant, les ordres étaient deux fois plus nombreux (notamment les ordres de position) en l'absence de liaisons radio. Les types de communications étaient sensiblement plus variés pour les soldats disposant d'une radio. La fonction de communication obéissait donc à des schémas similaires avec ou sans radio. Dans les deux cas, la fonction première de la communication portait sur la position, suivie de la situation. Cependant, avec la radio, il y avait moins d'échanges à propos de la position, et plus concernant la situation, par comparaison avec une simulation sans radio. Enfin, la durée des messages était à peu près la même dans les deux cas, mais l'information était un peu plus détaillée par radio.

Dans les deux modes, le chef de section et son adjoint étaient à l'origine du plus grand nombre de messages. Cependant, la communication était mieux répartie entre les divers rôles lorsque les soldats disposaient d'une radio. Ainsi, les membres d'un même groupe d'assaut communiquaient presque deux fois plus avec une radio que sans. En général, le commandant de la section communiquait surtout pour donner des ordres, puis pour transférer l'information. À noter qu'il faisait également des demandes, ce qui n'était pas le cas sans radio. Ces constatations s'appliquent également à son adjoint. Pour ce qui est des autres membres du groupe d'assaut, la radio servait moins à transmettre des ordres que des demandes et des accusés de réception. Pour ce qui est des échanges d'information entre les membres d'un groupe d'assaut, ils restaient à peu près les mêmes, c'est-à-dire très fréquents, avec ou sans radio.

Les résultats indiquent également qu'au sein d'une section disposant de liaisons radio, la plus grande partie du trafic circulait sur les réseaux à 4 membres des groupes d'assaut, suivis par le réseau du chef, et enfin par le réseau des 8 membres de la section. Ce résultat suggère une tendance à travailler au niveau des groupes d'assaut dont les dirigeants s'efforçaient de coordonner les actions au niveau de leur groupe particulier, et de diffuser l'information appropriée aux mêmes destinataires. Il n'est donc guère surprenant que sur le réseau du dirigeant, que le chef de section soit à l'origine de plus d'ordres et de moins de transferts et d'accusés de réception que son adjoint.

Alors que les résultats en termes de rendement et de processus d'équipe n'indiquent pas une supériorité évidente de la communication par radio, l'usage de la radio semblait accroître la charge de travail des participants. Cela peut être une conséquence du volume de trafic radio et de l'absence de procédures clairement établies. Les participants ont signalé quelques problèmes d'apprentissage pour l'utilisation du système radio, mais il est vrai que la simulation créait des problèmes de

coordination au niveau de l'ordinateur (mains sur le clavier), lorsqu'ils cherchaient à atteindre le bouton d'émission pour établir la communication.

Les groupes de discussion et les questionnaires finaux font ressortir un très large appui en faveur de l'ajout d'une radio. Les transferts et la coordination de l'information à l'intérieur d'un GA et entre les GA étaient jugés meilleurs avec une radio que sans. Cependant, de nombreux participants ont également exprimé des réserves à propos de l'utilisation des communications : liaisons occupées, tendance de tous à parler et à donner leur avis en même temps, plus de sérieuses préoccupations quant à l'effet de la fausse sécurité que procure la radio, pouvant entraîner un certain relâchement de la vigilance ou une certaine nonchalance. Certains ont également mentionné les risques inhérents à la radio si l'ennemi était capable d'intercepter des messages ou d'être à l'écoute. Ce dernier point suggère que la question du cryptage devrait être abordée dans de futures études. Enfin, quelques militaires ont exprimé l'avis que les signaux à main avaient l'avantage de matérialiser l'autorité du chef et la hiérarchie dans la communication au sein d'une section.

Les participants ont également été invités à porter un jugement sur les mérites des différentes configurations de réseau. Plusieurs étaient d'avis que seuls le chef et son adjoint devaient avoir des radios pour éviter la pagaille sur la fréquence. Une solution possible au problème de l'encombrement du réseau par des conversations multiples serait effectivement que les postes du chef et de son adjoint possèdent un bouton de priorité. Ils pourraient ainsi intervenir à leur guise. Une conclusion pertinente a été formulée par les participants, à savoir que l'utilité de la radio dépend de la dispersion physique de la section, la plupart convenant que la radio est un ajout utile lorsque les signaux à main ne sont pas possibles, mais qu'elle est inutile lorsque la section est regroupée.

Les implications pour la recherche future et les limitations de la présente étude sont en cours de discussion.

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1. Background

The SIREQ cognitive task analyses identified the ability to transfer information and to communicate between members in a dismounted infantry section as critical requirements for mission success. In the case of a typical execution phase of any mission, soldiers currently whisper or use hand signals, passed from person to person, during stealthy actions or use louder voices during engagement actions. Both methods have their shortcomings: hand signals require a line of sight between the sender and receiver and a short enough distance between the two parties so that the hands can be clearly seen, whereas raised voices indicate the speaker's location to the enemy, reveal intent to English speaking enemy, and run the risk of intelligibility problems or the message being unheard in noisy battle conditions. To overcome these current deficiencies in intra-section communications, most soldier modernization programmes have adopted an intra-section radio as part of their hardware ensemble.

Why an intra-section radio? Accepting the deficiencies in current methods of intra-section communication, the choice of a radio still raises a number of issues and opportunities for investigation. While the provision of a radio would seem intuitively attractive for addressing the transfer of information within the section, SIREQ must determine which, if any, performance parameters are enhanced by the use of a radio. Some possible advantages of the provision of a radio might include increased individual and/or collective status awareness, reduced individual mental workload, and improved team coordination and execution. Then, if some or all of these enhancements are realized by the addition of a radio, it will be important to determine whether these enhancements are sufficiently large enough to increase the likelihood and degree of mission success (e.g. fewer errors in execution, faster mission execution, fewer friendly casualties, more enemy casualties, fewer resources expended, etc.). It is likely that providing a radio will enhance some elements of individual and/or collective performance and that some of these enhancements will improve some aspects of mission outcome. The important questions are "which elements of performance are changed and why" and "which aspects of mission outcome are changed and why". At the same time, it is also important to understand the impact on various aspects of team process, such as perceived teamwork and workload. The impact of adding new equipment on workload must be understood, as well as possible impacts on team members' awareness of their own status (with respect to timings), as well as that of other section members.

What network configurations? Another feature of radio voice communications that has not been investigated concerns the choice of the most effective communications network configuration (i.e. who in the section should get a radio?). A number of network configurations are possible, for example:

- All members can receive but only the Section Commander (SC) can send;
- Only the Section Commander (SC) and second-in-command (2IC) have radios;
- All members can both send and receive;
- Radios are only provided to fire team leaders (i.e. every second soldier), etc.

Across this continuum of possible radio communication networks lie a number of issues. Does section performance improve as more members are provided with radios? Does the likelihood of radio communications diminish when the number of members in a network exceeds a certain value? For example, a junior rifleman may be inclined to ask questions, report information, and

make suggestions to his fire team partner or assault team leader but be very reluctant to voice the same points to all section members, including the SC. Within the range and type of information that can and should be transferred within a section exists an optimal network configuration for section operations; SIREQ needs to investigate the patterns and factors affecting intra-section radio voice communications to determine this configuration.

What information is exchanged? Investigating open radio voice communications among section members who are engaged in a mission scenario can also provide useful insights into the information transfer needs (push and pull) of different section roles. By providing section members with an open radio voice communications system, it may be possible to encourage an exchange of information that reflects what is actually required in a mission, but which is not currently available due to the limitations of the in-service methods of transferring information (i.e. hand signals, whispering, and yelling). By analyzing the flow and content of open and unrestricted voice communication within the section, it should be possible to distinguish the type and frequency of instructions sent, requests for different types of information, the anticipatory transfer of different information, and the coordination of communication between members. This analysis would provide a better understanding of the information exchange requirements within a section for a given mission, and would further highlight the deficiencies with the current in-service intra-section capability.

Which information exchange modalities? Once the information exchange requirements are better understood, it will be possible to assess which modality is best for exchanging various types of information. For example, a radio voice modality may not be the best method for providing location information in unmarked city streets. Using the radio modality, location information would likely be passed by describing one's location with reference to salient landmarks. Such a method would require a lengthy verbal exchange and would still be open to comprehension errors at the receiving end. In contrast, exchanging a picture of the city map marking the sender's location, the location information would be exchanged faster, more accurately, more reliably, and would require less transmission bandwidth.

The experiment described in this plan provides a first step toward investigating these and other intra-section communication issues by comparing the performance and patterns of information exchange within a section engaged in simulated missions using a computerized virtual environment. This experiment will serve as an exploratory effort to gain better insight into intra-section communication issues and measures. By starting with an experiment in a controlled laboratory environment to investigate and characterize intra-section communication, we will also be better able to identify areas for further experimentation and to develop and refine experimentation plans for the field.

2. Aims

In this exploratory investigation into intra-section communications, the following aims were pursued:

- To investigate the types, functions, and pathways of radio communications within a dismounted infantry section;
- To compare communications traffic across four network configurations;
- To compare team performance and process on missions with a radio communications network and missions without a radio communications network.
- To gather feedback from soldiers concerning their opinions on the advantages and disadvantages of the Radio versus No Radio conditions with respect to the perceived impact on team performance and process, as well as network configurations and hardware,

3. Method

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

3.1 Overview

An eight-day laboratory experiment was undertaken at the Defence Research and Development Canada Toronto (DRDC) over the period of 17 – 26 September 2001. Twelve (n = 12) reserve force infantry soldiers participated in 27 virtual-reality multi-player missions, while seated at a computer workstation, to evaluate the effects of adding a radio communications network to dismounted infantry operations. Approximately half of the missions included the use of a radio voice communications network while the communication in the other half paralleled that of regular infantry operations which do not use radios. For any one mission, eight soldiers worked together as an organic infantry section comprised of two assault groups (AGs), and engaged human enemy in the pursuit of a goal-based mission in a highly realistic, virtual urban environment.

Human factors (HF) measures included task performance, status awareness, workload, communication measures, and teamwork factors. Data collection included questionnaires, focus groups, and performance measures.

3.2 Equipment and Facilities

The 1st Person Gaming Laboratory included a series of thirteen PC workstations networked together by two distinct computing networks: the communications network and the gaming network.

3.2.1 Communications Network

A computerized communications LAN was developed to track and log all radio voice communications activity in each experimentation session. The communications network is comprised of a central PC server connected to a micro-processor driven switchboard unit, which manages the voice communication traffic for four voice networks for ten intercom units (see Figure 1 below). Each gaming workstation includes one intercom unit with four network "push-to-talk" buttons.

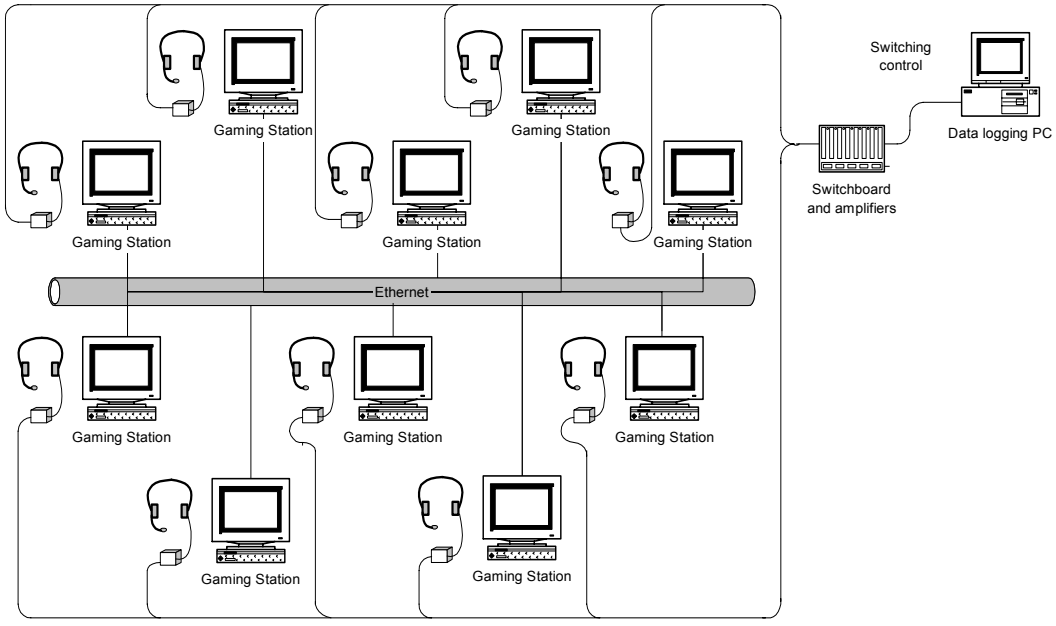


Figure 1: Communications network

Prior to the start of the experiment, soldiers were assigned membership to any or all of the four voice networks. To talk to other members of a network, a participant depressed the appropriate button and spoke into the boom microphone integrated into the gaming headphones. The switchboard detected and transferred the voice communication to one of four soundcards resident in the PC server. The server then logged the time, sender identification, and network (thereby identifying the list of listeners), and stored a digital record of the communication in a WAV file.

The ambient noise from the gaming network (e.g. footsteps, rain, rifle fire, and explosions) was ported from the gaming stations to the gaming headphones so soldiers could simultaneously hear the gaming audio track and any radio voice communications.

3.2.2 1st Person Gaming Network

The 1st Person Gaming network was developed to achieve a virtual mission environment where goal-based collective infantry tasks can be undertaken by a team of soldiers in real time. The gaming network is comprised of thirteen PC computer workstations connected by a local area network (LAN) to a PC server. This network configuration links the workstations together in a multi-player virtual mission environment. Each workstation can be assigned to any number of friendly or enemy teams within a given mission depending on the software gaming environment chosen for the experiment.

For this experiment, Rogue Spear (Urban Operations package) was selected as the software gaming environment (see example screenshots in Figure 2).

Figure 2: Rogue Spear screenshots

Rogue Spear provides a highly realistic, and richly rendered, simulation environment with a wide variety of mission maps in a range of operational conditions (e.g. rain, snow, sun, indoors, night, etc.). Soldiers in the game view the simulation environment from a first-person perspective, through the eyes of their computer avatar, and can observe the actions of other soldiers in real time. The clothing, weapons, body armour protection, and characteristics of each participant in the game can be standardized or customized as necessary.

Rogue Spear can also track and record certain individual and mission variables: number of shots fired, number of hits, number of casualties, etc. As well, the gaming network includes one workstation dedicated to capturing a real time record of participant movements and engagements on the mission map from a 'bird's eye' perspective. Subsequent playback of mission recordings can then be used to evaluate mission timings and team coordination.

3.2.3 Laboratory Layout

The laboratory layout (Figure 3) was configured to achieve a number of goals.

1. Separate the two AGs as much as possible;
2. Minimize the distance between members of a AG to facilitate the use of hand signals;
3. Situate the two computer networks in the middle of the workstations for ease of cable management; and
4. Position the controller and enemy workstations centrally, facing out towards the two AGs for monitoring purposes.

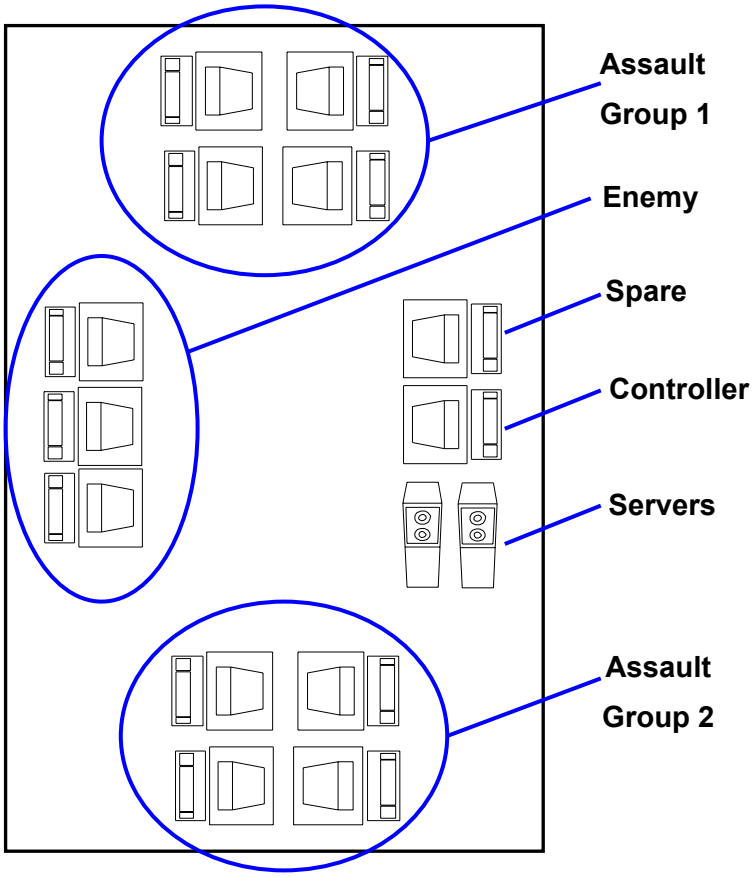


Figure 3: Laboratory Layout

To minimize the opportunities for soldiers overhearing radio voice communications that were not intended for them, a 'whisper track' of unintelligible voices was played in the lab during each mission. In addition, in order to increase immersion into the simulation, the lights in the lab were turned off while each mission was active.

3.3 Participants

Twelve (n = 12) infantry reservists were organized into three teams of 4. Each AG was comprised of a leader and three soldiers (Cpl. or Pt. rank). Each section had a different SC, drawn from the AG leaders. Eight-man sections were configured and reconfigured such that each AG was teamed with each of the other two AGs. Thus, only 8 soldiers played the game at one time, comprising reconstituted sections that were generated from three 4-person groups.

Section 1 = Assault Groups A and B, Section Comd. = Group Leader A.
Section 2 = Assault Groups A and C, Section Comd. = Group Leader C.
Section 3 = Assault Groups B and C, Section Comd. = Group Leader B.

3.4 Experimental Conditions: No Radio/Radio

To evaluate the effects of intra-section radio voice communications, two communications network options were assessed in this experiment: a no radio option and an enhanced radio communications network.

a) No Radio Condition: In the no radio option, the radio voice communications network was partially disabled, by eliminating the communication audio to the headphones. During two proof of concept missions, soldiers were initially instructed to use hand signals to indicate a need to communicate with other members of their individual AG, *using the motions of their computer avatar*. Within the Rogue Spear game (Urban Operations mission pack), there 3 main signals available, including "On me", a request for other members of the AG to gather around the section commander, "Halt", and pointing in a direction. Just prior to employing a hand signal, soldiers were instructed to depress their AG intercom button and voice the hand signal instruction. This logged the time and type of hand signal sent (e.g. "signal – HALT"). Soldiers were instructed to abide by two pre-requisites for employing hand signals:

- Unobstructed line of sight to the receiving soldiers in the virtual environment; and
- Suitable visibility (i.e. sufficient light and no obscuration such as fog, rain, etc.).

During initial proof of concept testing using hand signals, a number of problems emerged. The motions associated with some of the hand signals within a 3D dimensional environment proved difficult to understand, depending on the relative position of soldiers. With a straight–on view of a leader, for example, it might have been possible to understand the direction that the leader was pointing to without supplementary communication. Without such a view, however, deciphering the proper direction (even with repeated pointing) was extremely difficult. Further, using only these signals would alter the communications in a way that was unrealistic given that computer avatars were essentially asked to be side by side in the game, but to not communicate other than through 4 signals. In an actual infantry situation, on the other hand, even soldiers without radios would be able to communicate when in relatively close physical proximity with other soldiers. As such, to restrict communications to only hand signals would have been more restrictive than would be the case in real life infantry situations.

As such, the experimental protocol was altered to better reflect the communication status within assault teams in actual missions. In the experimental missions, soldiers were asked to communicate only when they had a close and unobstructed line of sight to receiving soldiers, as before. Further, as a result of the proof of concept, soldiers were also allowed to communicate the same kinds of messages that they might in a real life situation when extremely close, but to use a hand signal when possible to indicate a desire to communicate. Each communication was logged by the initiator of the communication depressing the AG intercom button, and by voicing the communication given to the other soldier(s). Experiment staff monitored the AG to ensure these conditions were met.

b) Radio Communications Network Condition: In this option, all four communication system networks were utilized to provide soldiers with a full range of communication network options. The four networks were configured as follows:

Network #1 = Sect. Comd and 2IC only;

Network #2 = Sect. Comd Assault Group 1 members only (i.e. four soldiers);

Network #3 = 2IC Assault Group 2 members only (i.e. four soldiers); and

Network #4 = All Section members (i.e. all eight soldiers).

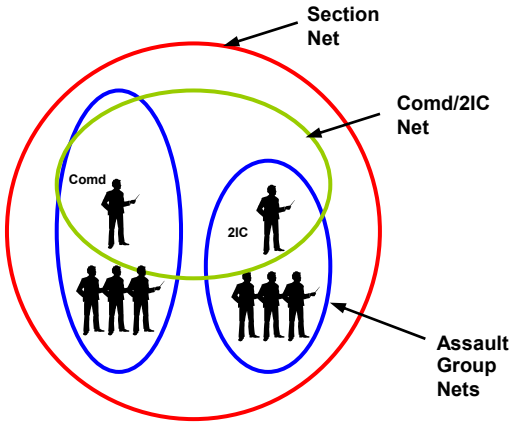


Figure 4: Communication network configuration

Since the SC and the 2IC each led one of the two AGs, they had possible access to three networks. The remaining riflemen had access to two networks (i.e. their AG and the larger section Network). The members of all networks had the ability to both receive and initiate communications from other network members.

3.5 Mission Descriptions

The missions used in this experiment provided a goal-oriented, team-based scenario in a contextually relevant small Unit, infantry context, with functionally realistic environmental and terrain conditions. A sample mission map is presented in Appendix A. The experimental approach for each mission is outlined below, and aspects of the mission setup are described.

3.5.1 Outline Approach

The experimental approach is described below for each of the briefing, execution, and endex phases of the mission.

a) Briefing Phase: Prior to each mission, the section was briefed via videotape by an Army reserve platoon leader using an overhead map of the mission terrain. Each briefing included:

- A statement of the mission goal;

- An indication of the mission objective and the approach routes for each AG;
- Actions on contact, snipers, obstacles, etc;
- Timings necessary to coordinate the assault; and
- Outline of known enemy locations and strength.

All members of the section were then given the opportunity to study the map. The section Comd. and the 2IC then formed a plan, which they communicated to the AG as a whole before breaking up into separate AGs and discussing the specifics of their route and mission. When the leaders of both AGs indicated readiness to proceed, the mission scenario began.

b) Execution Phase: In preparation for the start of each mission, the enemy (played by trained confederates) assumed their predefined positions in the mission map. Both AGs were positioned at their respective insertion points in the map and the mission clock was initiated.

Each AG was required to move tactically with stealth along their assigned approach route. Enroute the AG encountered physical obstacles, which required them to modify their route and to coordinate their movement. In addition, AGs also encountered single enemy soldiers that needed to be eliminated. Each mission required one AG to provide coordinated fire support to the other AG in the crossing of open ground, the engagement of enemy enroute, or the breaching of the objective building. At a pre-selected point in the progress of each mission, the experiment controller froze the mission to allow for the collection of status awareness data.

Having maneuvered to the objective building or structure, the two AGs then began a coordinated assault on the objective. Each mission required the AG to enter and clear the objective building from different approaches (i.e. without line of sight between Groups). In most cases, this required the section to clear several floors of the objective building by engaging and dispatching enemy soldiers as they were encountered, while being mindful of the likely location and status of the other AG. Throughout each mission, mission outcome and communications data (voice and verbalized hand signals) were logged and archived for subsequent analyses.

c) Endex Phase: Following the completion of each mission, soldiers completed two questionnaires (i.e. teamwork questionnaire and mental workload questionnaire). At the end of this study, all soldiers were involved in a 2-hour focus group, in which they were given the opportunity to describe their experiences in this study.

3.5.2 Mission Maps

The ten mission maps selected for this experiment included a mixture of open country (typically a limited area for insertion, approach, withdrawal, and extraction), and urban terrain with a combination of urban streets and in-building activities. Mission maps were selected for the following features:

- A network of approaches or streets, to be used to reach a range of buildings for an assault. It was necessary to be able to assign each AG a different approach route to the objective. Each route also had to be visually obstructed to ensure that the AG could not observe each other during the critical part of the mission.

- Sufficient complexity of terrain in both the streets and the buildings to ensure that soldier movement required monitoring, control, and coordination.
- Adequate structures and obstacles to enable the effective use of enemy forces during both the approach and the assault.
- A number of possible insertion points in the map to ensure that a mission could be repeated using a different approach and assault route for each AG.

3.5.3 Enemy

The Enemy was used as a means of delaying and obstructing the AG. This role was played by experimental staff. By placing enemy in key locations, enemy presence would require the two AGs to use communication to coordinate their movements and their fire. Enemy movement and weapons were limited, however, so that they could not kill the AG, but they could be killed by them. The fact that the enemy were played by people meant that we could anticipate and react to AG actions. There were 4 active enemies within each mission, each positioned at predefined points which provided cover within the mission map, or that challenged the AG at critical points within the mission (e.g. at the rendezvous points). There were 3 enemies that presented themselves during the course of the mission, and one final enemy at the mission objective. When this enemy was killed, the mission ended. Enemies were asked to engage the appropriate AG, and to provide opposition for between 15 to 30 seconds.

3.5.4 Casualty Control

For this experiment, enemy soldiers were able to shoot at and hit AG Soldiers, but the game software was configured to ensure that members of the AG could not be killed by enemy force bullets. The number of hits sustained by each participant was analyzed as an indication of survivability. Enemy soldiers were configured such that they could be killed by the assaulting forces.

3.6 Dependent Measures

Data were collected for the following dependent measures at the start and end of the experiment, during the execution of each mission, and following the completion of each mission.

3.6.1 Start of the Experiment

Participant data were collected prior to the start of the experiment to characterize the subject sample and to provide a basis for matching AG based on the profiles of soldiers in each group (i.e. to make the groups as similar as possible).

- Participant Characteristics: Soldiers completed a questionnaire detailing their military and computer gaming experience, which were used to organize the membership of each AG:
  - Military Experience: years in the infantry, rank, field experience in small Unit tactics, particularly urban operations; and
  - Computer Gaming Experience: familiarity with computer use, experience with 1st Person shooter games, experience with Rogue Spear.

3.6.2 Mission Freeze

During the course of a mission the game was paused to query soldiers for the following information.

- Status Awareness: At a critical stage of the mission (e.g. immediately following an engagement with the enemy) the game server was paused and soldiers rated their knowledge about casualties and timings of the other assault group, and the timings of their own group.

3.6.3 Throughout each Mission

Outcome and communications data were collected throughout the course of each mission.

Communication Measures: The radio voice communication measurement approach has been adapted from Entin, Entin, MacMillan, and Serfaty (1993). The process of content analysis began with a member of the experimental team listening to a large sample of the communications from both the Radio and No Radio conditions. This process yielded a number of additional categories needed to describe the communications evidenced. Once a tentative categorization framework was created, two members of the experimental team worked together to evaluate and revise the framework. This involved two individuals listening to more transmissions, working individually to categorize the type, function and referent of the transmission, then meeting to discuss their decisions, and further refining their understanding of each category until they reached agreement on the categorization process. Another important component of this process was deciding on a unit of information. As many of the transmissions contain several distinct pieces of information, it was important to use a common strategy for delineating units of communication. A "unit" of communication was defined as one discrete thought. After this work, experimenters each did independent content analysis on a sample of transmissions. Their agreement was very high at more than 90%. The framework developed during their process was used for all subsequent content analysis.

Using the data capture capabilities of the radio voice communications LAN and a review of mission activities, each communication was classified for the following variables, in chronological order.

- Type: Messages were first classified as either a "Transfer" of information, a "Request" for information, an "Order" to perform some task, or an "Acknowledgement" of receipt of any of the latter message types. Classifications of "Communications Check", "Informal Order", and "Getting Attention" were added after an early overview of the communications logs.
- Function: Each message was then classified by its information transfer function. Functions describe the purpose for transferring the information and include "Status", "Location", "Task Assignment", and "Planning/Problem Solving". Functions related to "Game Keys" and "Repeat Message" were also included.
- Enemy/Friendly: For functions involving "Status" or "Location", the message was further classified as relating to "Friendly" forces, "Enemy" forces or "Undefined Enemy Forces".

In addition, each message was also categorized according to:

- Pathways: The three radio voice communications networks represented information transfer pathways between different roles and groupings within the experiment. Using the radio voice communications LAN software, each message from channels 1 and 2 was logged according to the networks described in section 3.4.

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 information pertaining to "Location" of "Enemy". 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 information pertaining to "Location" of "Enemy". The leader's 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.

The following measures were then determined for each of the message classifications (i.e., type and function) and categorical variables (i.e., pathway).

- Communication Rates: The frequency of voice exchanges, as both the number of messages per minute and as the relative frequency of messages, was determined overall for each mission and specifically for each of the categorization and classification groupings.
- Message Duration: To provide some insights into the size of the messages sent, the duration of each message was calculated.
- Anticipation Ratios: The ability of team members to anticipate the information needs of other members is an indication of teamwork and coordination. 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).

Measures of Outcome: For each AG, mission outcome data were collected throughout the mission for the following variables:

- Rounds Taken: While friendly forces could not be killed, data on the number of hits sustained by each member and the AG as a whole were recorded (i.e. rounds taken).
- Ammunition Use (Rounds Fired): The number of rounds expended by the AGs, and the section as a whole, were recorded.
- AG Deaths: Even though AG members could not be killed by enemy bullets, it was possible for them to kill themselves or their teammates with their own grenades. The number of deaths incurred by AG members through inappropriate use of grenades was recorded.

3.6.4 End of each Mission

Having completed the mission, soldiers completed questionnaires concerning the following data:

a) Teamwork Measures: Soldiers completed a teamwork questionnaire to assess the performance of each AG, and the section as a whole, for a variety of teamwork dimensions: e.g. anticipation of information needs, coordination, communication behaviour, monitoring behaviour, feedback behaviour, back-up/covering behaviour,

and team orientation. Participants rated teamwork on a 7-point Likert scale where 1 equalled "Strongly Disagree" and 7 equalled "Strongly Agree" (Figure 5).

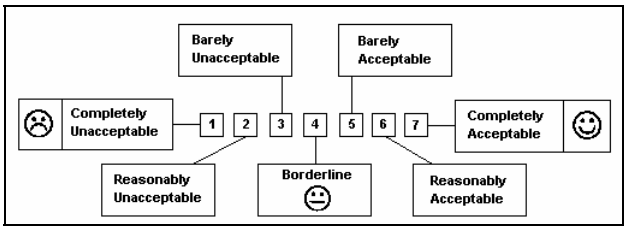


Figure 5: The seven-point acceptability scale

b) Mental Workload: Soldiers also completed a NASA TLX questionnaire, indicating the levels of subjective workload experienced during the mission. NASA TLX requires the participant to rate six measures of workload which mostly refer to 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".

3.6.5 End of the Experiment

After groups completed all missions in each communication condition (i.e. no radio vs. the radio communications network), a final exit questionnaire was administered followed by a focus group in order to discuss the soldiers' opinions about and experiences with the following issues:

- The experimental approach and the use of the 1st Person gaming environment;
- The benefits and drawbacks of having radio comms or not;
- Lessons learned about the use of a radio voice communications network for information transfer;
- The opportunities for exchanging different types of information in different modalities; and
- The implications of an information exchange network on small team tactics.

3.6.6 Experiment Design Overview

While the small sample size of this experiment prevented extensive inferential analysis, the exploratory nature of this study provided useful insights into small unit information exchange and coordination issues. These insights will be critical for planning the methodological and sample size requirements for future SIREQ experimentation into group (i.e. section and AG) information needs.

Table 1 outlines the missions for each Radio and No Radio condition in this experiment. Each section was originally designated to complete a total of 10 different missions. However, due to changes to the experimental protocol, it became necessary to designate some of the first missions as proof of concept missions. The resulting sample sizes for the Radio and No Radio conditions for each section are indicated below.

Table 1: Missions by section and condition

Section	Assault Group	Radio Network	No Radio
1	A	5	4
	B		
2	A	4	5
	C		
3	B	4	5
	C		

The ten Rogue Spear mission maps selected for the experiment were randomly assigned a mission order. Each mission map had two separate insertion points and approach routes per mission. Mission presentation for each section was balanced for the mission insertion point, the associated AG route, and Radio/No Radio condition. Unless indicated otherwise, all statistical analyses were performed using dependent t-tests within subjects.

3.6.7 Experiment Schedule

Table 2 outlines the eight-day experiment schedule. The trial was organized into three blocks: briefings and training, daily experimentation, and a wrap-up session.

Table 2: Trial schedule

13 – 21 September 2001				
	Day 1	Day 2	Days 3 – 7	Day 8
	Briefings / Training		*Daily Experimentation*	*Wrap-up*
Morning	Experiment Briefing Rogue Spear Briefing	Group Training	1st Mission 2nd Mission 3rd Mission	1st Mission 2nd Mission 3rd Missio
Lunch				
Afternoon	Individual Training	Group Training	4th Mission 5th Mission 6th Mission	Exit Focus Group

3.7 Briefings / Training

All soldiers were briefed on the goals and outline approach to the experiment. Soldiers were required to complete the Participant Questionnaire so that AGs could be formed with similar levels of military and computing experience. There were 3 soldiers with extensive experience with the Rogue Spear software, as identified in the personal information collected prior to group assignment. These soldiers were spread evenly across the 3 AGs (i.e. one per group). The features and gaming environment of Rogue Spear were demonstrated to the soldiers.

Training was comprised of individual and group training. Individual training included instruction and practice in movement, posture, and target engagement skills. The Rogue Spear gallery range and obstacle course were used to train fundamental skills, enabling the measurement of each soldier's training progress. Individual skills were then combined in a mission context by training soldiers in the single and multiple kill-house training scenarios in the Rogue Spear game. Each participant was required to pass through the kill-house training before advancing to the team training.

Group training comprised experience with both team interaction and coordination in the Rogue Spear environment, and the use of communications. Group training (i.e. four–person AG) involved practice missions against computer-generated enemy, using mission maps that were different from the experiment maps. AGs were required to practice both the no radio and the radio voice communications network. Soldiers were encouraged to use the system liberally to gain insight into the best means of employing the radio network prior to experimentation. In addition, as part of their training, soldiers also learned about the use of hand signals within the game, how to activate them, the conditions under which hand signals could be used to initiate conversation, how to coordinate the use of hand signals with initiating face to face voice communication when extremely close as described earlier, and how to log their communication.

3.8 Daily Experimentation

During each experimentation day, soldiers engaged in approximately six missions. The breakdown of the timing of each phase of the missions was as follows:

Mission Brief	10 minutes
Section Planning	15 minutes
Mission Execution	30 minutes
Endex Measures	15 minutes

The mission brief was provided by a reserve force officer 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 status 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.

4. Results

4.1 Participant Characteristics

Soldiers completed a questionnaire detailing the following information, which was used to organize the membership of each AG.

Military Experience: The twelve soldiers in this study were infantry reservists from the Toronto, Ontario area. Participants consisted of 7 Ptes. and 5 Cpls.

The soldiers who participated in this trial had a wide range of land force experience, with 1 soldier having been in the military for less than a year, eight having served between 1 year and 5 years, and 3 soldiers having served over 5 years.

In terms of operational experience, only 4 of the 12 had experience, and this experience was in Bosnia, Croatia, Kosovo and another unspecified location.

Using a 5-point scale ranging from "terrible" (1) to "excellent" (5), soldiers rated their own abilities on several skills relevant to the military domain (e.g. reading maps, using hand signals and engaging targets), as well as their military experience and/or training in planning missions and conducting section assaults. These results are depicted in the table below.

Table 3: Military skill ratings

Skills	Mean (StDev)
Planning skills	3.8 ± 0.8
Map reading skills	3.7 ± 0.8
Hand signal communication skills	4.2 ± 0.7
Tactical movement skill	4.0 ± 0.9
Target engagement skill	3.8 ± 0.9

As can be seen, all soldiers rated their military skills slightly above average on the skill items.

Soldiers also rated their actual training and/or experience planning missions, indicating either "no experience" (1), "some" (2), "moderate" (3), or "extensive experience" (4). As Table 4 shows, on average, soldiers indicated that they had some experience planning missions and in conducting section assaults, and only slightly more experience conducting urban operations.

Table 4: Military experience ratings

Experience	Mean (StDev)
Training and/or experience planning missions	2.1 ± 0.7
Training and/or experience conducting section assaults	2.3 ± 1.0
Training and/or experience in urban operations	2.4 ± 0.7

Computer Gaming Experience: Using the same scale, soldiers' general experience using computers and their experience with 1st person shooter games, such as Rogue Spear, was explored.

As would be expected, there was a range of experience in general computer proficiency. On average soldiers indicated a moderate level of experience with computers. In terms of experience with 1st person shooter games, four soldiers indicated no experience, three soldiers indicated some experience, and three soldiers indicated extensive experience with 1st person shooter games.

Table 5: Computer experience ratings

Computer Experience	Mean (StDev)
Experience with computers	2.8 ± 0.9
Experience with 1st person shooter games	2.4 ± 1.2

4.2 Overview of Communications

Each of the three sections completed 9 missions, for a total of 27 missions. Content analyses were conducted on the 13 radio missions and 14 no radio missions.

In the Radio condition, there were 2317 wav files containing 2822 discrete units of information or transmissions. It was possible, of course, for a wav file to contain multiple communications. The mean number of transmissions within each of the 13 radio missions was 217.

Table 6: Wav files and transmissions

	N	# wav files	# of transmissions	Mean # of transmissions per mission
Radio	13	2317	2822	217.1 ± 84.8
No Radio	14	233	270	19.4 ± 8.3
Total	27	2550	3092	

In the No Radio condition, there were 233 wav files and 270 discrete transmissions. The number of transmissions within the 14 individual missions varied, with a mean of 19.4 transmissions in each, and a standard deviation of 8.3.

Clearly, communication was much more frequent when the AG had radios than when they did not, at a ratio of about 10 transmissions in the radio sessions to every 1 transmission in the no radio sessions.

4.2.1 Type of Communication

The important question, however, is whether the content of communications changes when section members have a radio in comparison to current operations in which they do not. The chart below

compares the types of communication in the Radio vs. No Radio conditions, as a proportion of the total communication within each. [1]

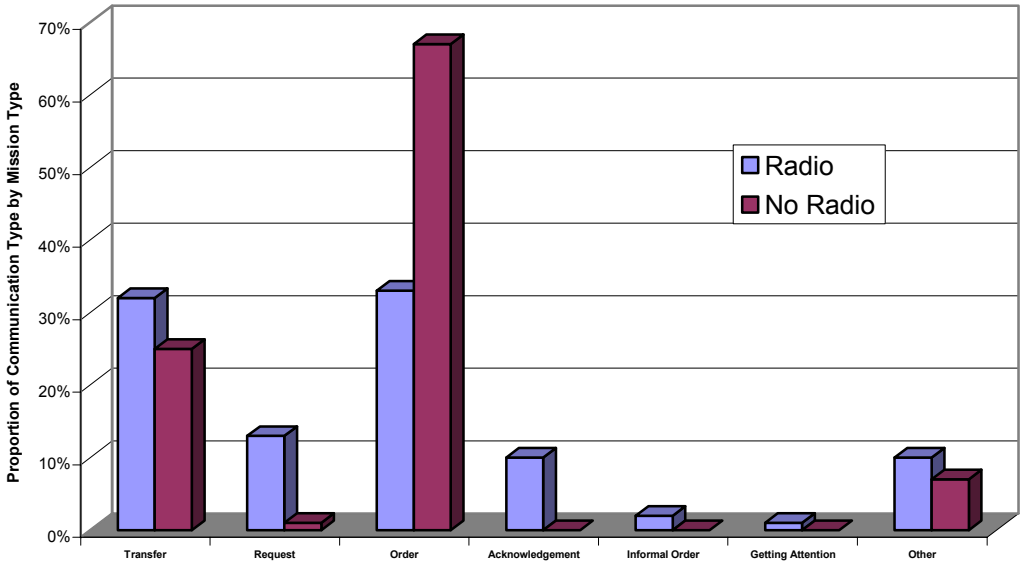


Figure 6: Type of communication by condition

When AGs did not have radio communications, orders were by far the most frequent form of communication, accounting for 67% of all transmissions. The next most frequent transmission was transfers at 25%, and all other categories combined at less than 10%.

When AGs did have radio communications, on the other hand, the types of communication used were somewhat more differentiated. Transfers were more frequent in the Radio condition, comprising around 31% of total transmissions, and orders were again the most frequent form of transmission at about 32% of the total. However, requests comprised about 12% of transmissions and acknowledgements about 8% of total transmissions. In general, this suggests that when infantry sections have radios, the type of communication that they use is more varied and differentiated. Without radios, communication is used primarily for giving orders and for transferring information, presumably to keep other teammates informed about one's actions.

4.2.2 Function of Communication

It is important to note that not every type of transmission was associated with a specific function. This is the case, for example, with button presses (occurring when participants clicked the PTT but did not engage in conversation), whose function was indeterminate within this experiment. Within both the Radio and the No Radio conditions, 80% of transmissions were seen as having a functional aspect.

[1] The "other" category includes items that were recorded wav files, but are not true communication (e.g. comms checks before missions started, or button presses produced because of participants clicking the comms button). A detailed breakdown of these items is presented in Appendix A.

The chart below shows the breakdown of the various functions that communication served when infantry sections had radios vs. when they did not have a radio.

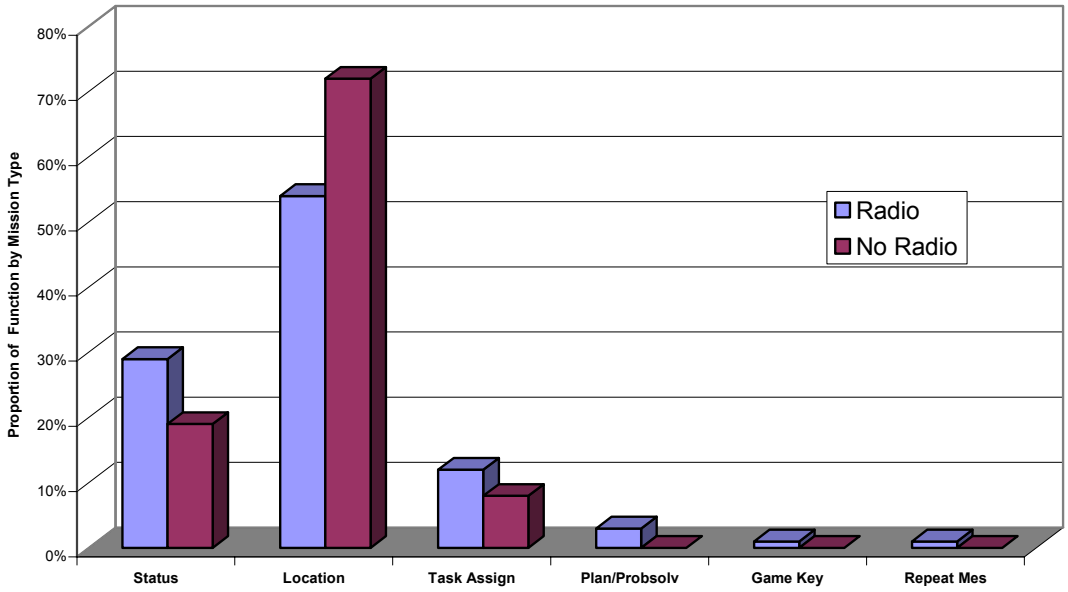


Figure 7: Function of communication by condition

Both with radios and without, the primary function of communication was related to location. Statements related to location comprised 51% of function-related transmissions with radios, and 68% of the function-related transmissions without radios. Status was the next most important function served, comprising 26% of the transmissions when AGs had radios and 15% of the transmissions when they did not. Giving task assignments was slightly higher with a radio than without.

4.2.3 Combined Type and Function

Most transmissions contained information relevant to both type and function. The table below lists the 8 most frequent forms of communication noted during the missions, and their relative frequency with and without a radio.

Table 7: Combined type by function frequencies by condition

	Radio Relative Freq	No Radio Relative Freq
Order regarding location	30%	60%
Transfer of status	18%	18%
Order regarding task assignment	9%	7%
Transfer of location	17%	-
Request status	8%	-
Request location	6%	-
Transfer task assignment	3%	-
Transfer plan/problem solving	2%	-
Others	8%	9%
Total	100%	100%

Without a radio, orders for location were by far the most common form of communication, accounting for 60% of the total number of no radio communications. With a radio, orders concerning location were less important, but were still the most important form of communication. Transfers of all types of information (particularly related to location) played a more important role with a radio, as did requests for status and location. Again, this analysis suggests more differentiated communication in the Radio condition.

4.2.4 Friendlies vs. Enemies

Each item of communication was also categorized as to whether it described friendly forces, enemy forces, or undefined enemy contact. Undefined enemy contact was defined as indirect references to enemy forces (e.g, "what's out there?").

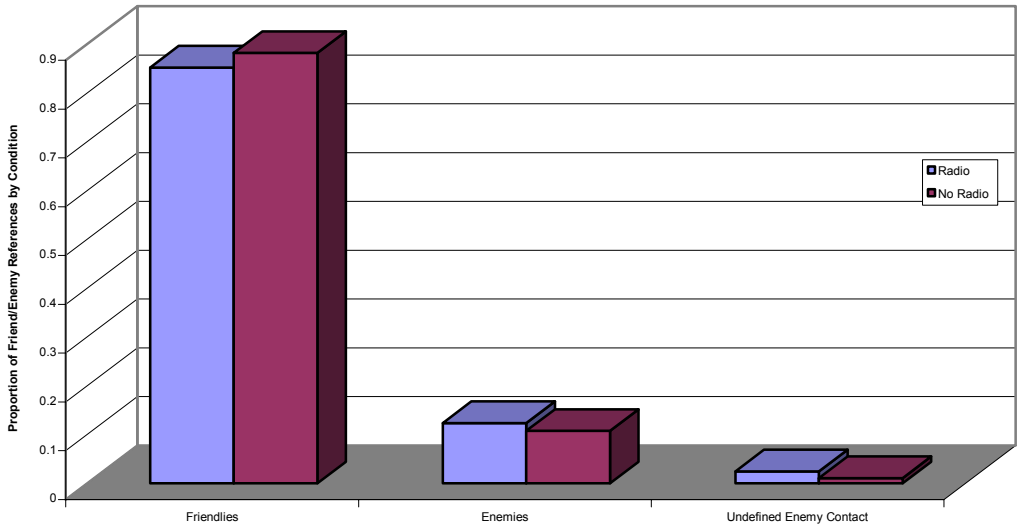


Figure 8: Friendly/enemy references by condition

In the missions with a radio, 81% of the communications had a clear referent to friendlies or enemies, with 69% devoted to friendlies, and about 10% devoted to defined and 2% to undefined enemy contact. When AGs did not have a radio, 93% of the transmissions had a clear friendly or enemy referent.

4.2.5 Message Duration

To provide some insights into the size of the messages sent, the duration of each message was calculated. Message durations are shown in Table 8.

Table 8: Message duration (seconds)

	Radio	No Radio
Transfer	2.2 ± 1.3	2.5 ± 1.5
Request	2.2 ± 1.2	2.5 ± 0.7
Order	2.1 ± 1.3	1.3 ± 1.1
Acknowledgement	1.2 ± 1.0	-
Informal order	1.8 ± 1.2	1.0 ± 0.1
Getting attention	1.7 ± 0.9	-
Other	0.9 ± 1.0	1.3 ± 1.1
Total	1.9 ± 1.3	1.6 ± 1.3

In general, message durations in the Radio and No Radio conditions were very similar, other than orders being perhaps more elaborated in the Radio condition, and communications about transfers and requests were slightly longer.

4.2.6 Pathways of Communication

In order to understand the pathways of communication, the communications were also analyzed in terms of the frequency with which speakers in different roles transmitted messages in both the Radio and No Radio conditions. This analysis is noted in Table 9 below:

Table 9: Frequency of communication by role

	SC	2IC	AG members	Total
Radio	1016	988	818	2822
No Radio	130	97	43	270
Total	1146	1085	861	3092

As noted earlier, the overall ratio of radio to no radio communications was about 10 to 1. This ratio was consistent for SCs and 2IC's, but was somewhat more extreme for AG members, with the ratio here at about 20 to 1 (radio vs. no radio).

It is also possible to consider the relative proportion of communications within each role in relation to total communication within each condition (i.e. radio or no radio). Figure 9 shows this.

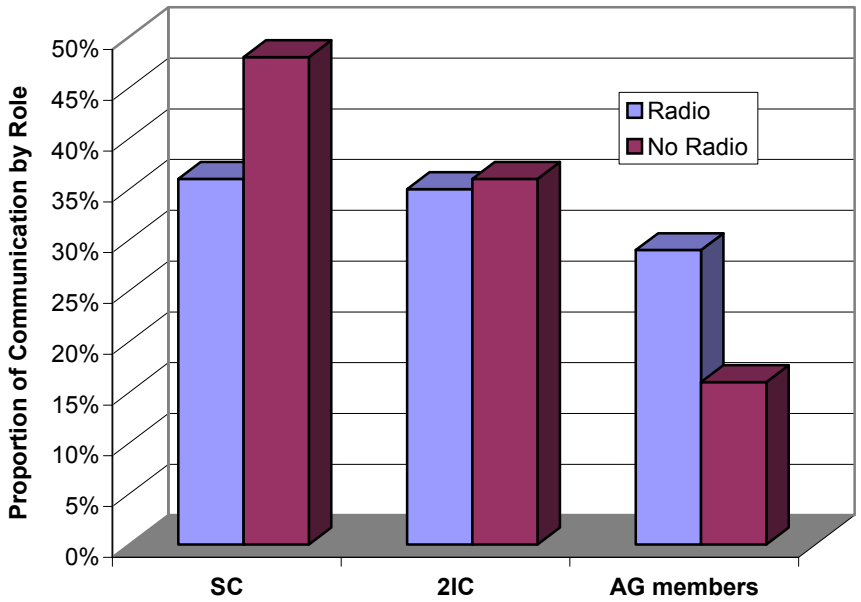


Figure 9: Communication by role

The proportion of traffic generated by the SC was somewhat lower when radios were used, generating only 36% of the total radio traffic in this condition, but about 48% in the No Radio condition. The role of the 2IC was relatively consistent in both Radio and No Radio conditions, at about 37 and 39%. The most dramatic change occurred in the AG members' traffic. Without a radio, AG members generated only 16% of the traffic. On the other hand, they generated considerably more traffic at 29% when they had a radio. This suggests that radios allow for a more equal distribution of communication within an AG. Without them, the AG leaders shoulder the burden of communication.

If it is the case, however, that having radios changes the proportion of communication transmitted by section members in varying roles, it is also important to ask how the content of this communication compares within the differing roles and between them. In other words, do SC's send out different kinds of information when they have a radio than when they do not? How does their communication differ from that of section members?

As Figure 10 shows, for SC's, the frequency of orders exhibited the most marked change.

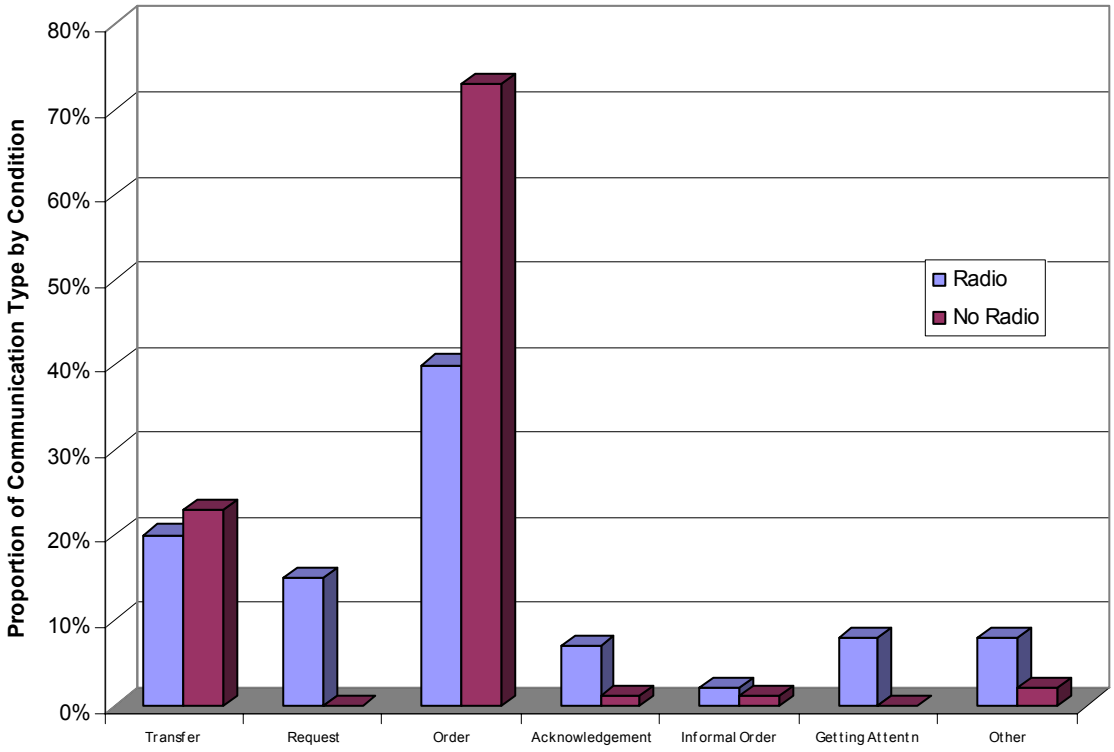


Figure 10: SCs – Type of communication

Without a radio, orders comprised 72% of total transmissions, whereas with a radio, orders comprised only 47% of total transmissions. Moreover, SC's made no requests when they were without a radio, but requests represented 14% of their total communications with a radio. Similarly, an increase in acknowledgements and getting attention was evidenced in the Radio

condition. The proportion of transfers, however, was relatively consistent whether they had radios or not.

As shown in Figure 11, a similar pattern held for 2IC's.

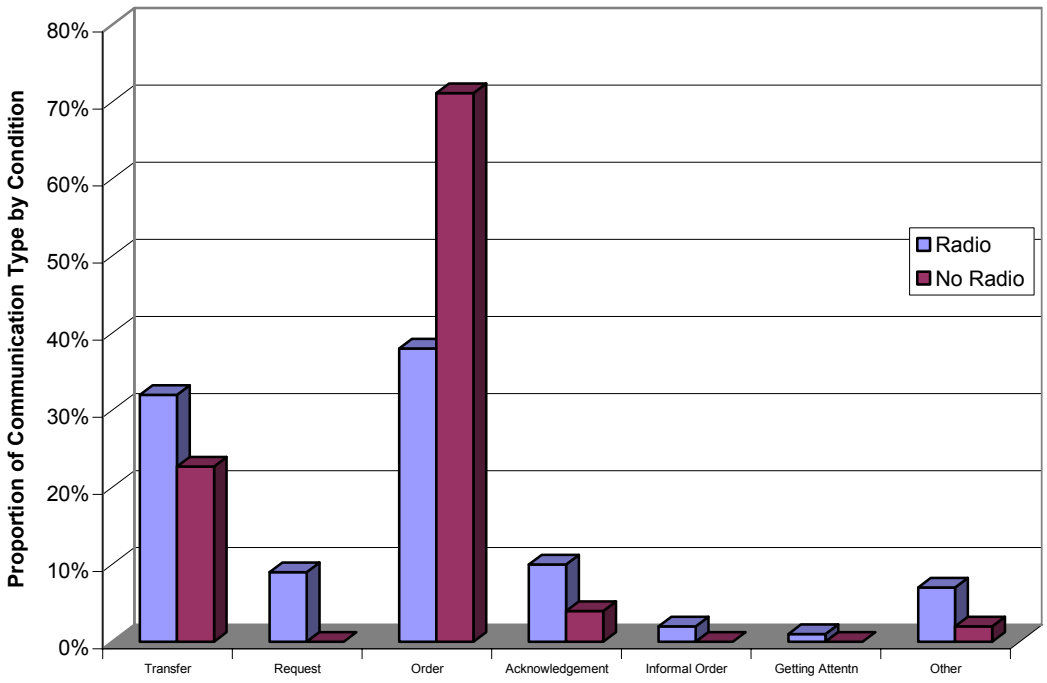


Figure 11: 2IC's – Type of communication

The most prominent form of communication was orders, particularly when they did not have a radio. However, this frequency count diminished in the Radio condition. In addition, 2IC's transferred more information when they had a radio than when they did not. This analysis again seems to support the notion that one of the advantages of having a section radio is that it makes missions more equally distributed in power, as evidenced by fewer orders, but higher rates of transfers and requests by AG leaders.

In general, as Figure 12 shows, AG members communicated more often when they had a radio available than when they did not.

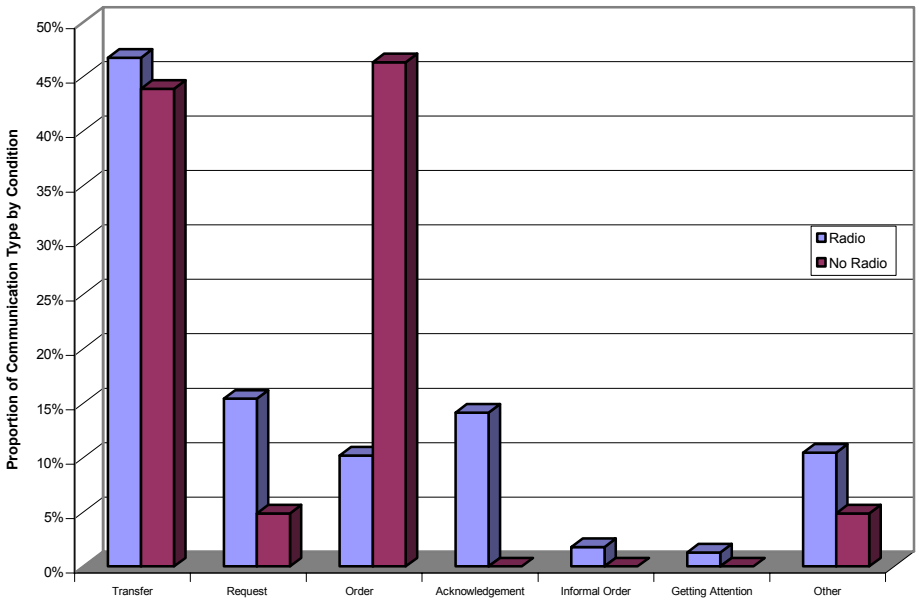


Figure 12: AG members – Type of communication

The proportion of transmissions of transfers stayed relatively similar between conditions. On the other hand, requests and acknowledgements saw increases in the Radio condition, whereas orders saw a large decrease.

4.3 Network Radio Communication

Four different radio networks were created, which allowed soldiers in different roles to choose the network on which they would communicate with others. Several questions emerged from this configuration. How frequently would each of the networks be used? What kinds of communication would dominate each of the networks? Table 10 shows the frequency of radio transmissions over each of the 4 networks.

Table 10: Transmissions by network

Network #	Composition (# members)	# Transmissions
1	SC and 2IC (2)	793
2	SC's assault group (4)	896
3	2IC's assault group (4)	952
4	All section members (8)	181
Total		2822

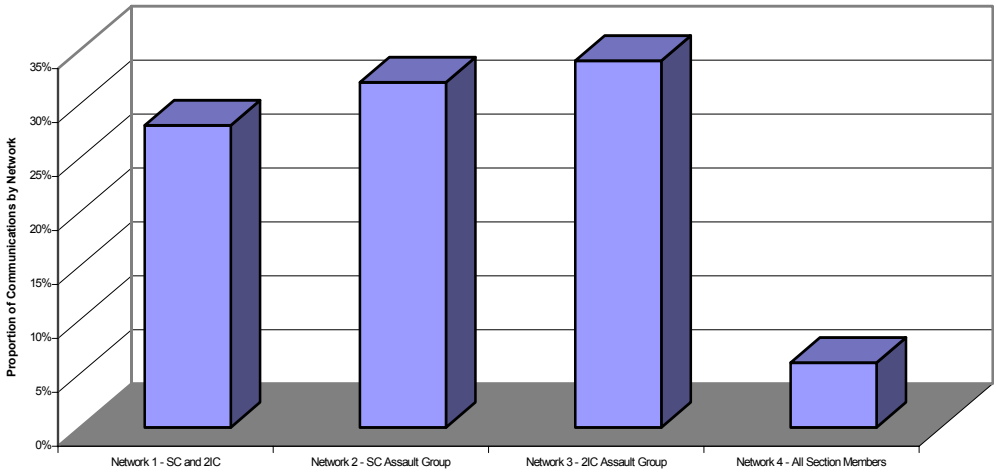


Figure 13: Breakdown of radio network communication

As Figure 13 shows, the SC and the 2IC network was fairly active. Although there were only 2 people on this network, it generated almost as much radio traffic as the larger AG networks that each had 4 members. The distribution of radio voice communications on the SC and the 2IC AG networks was relatively balanced. Perhaps most surprising, however, was the relatively low proportion of transmissions on Network 4, the open communication network provided to all 8 members of the AG. This network accounted for only 6% of the total traffic on the radio networks.

4.3.1 Network 1 - SC and 2IC Network (2)

This network, exclusively for communication between the SC and the 2IC, generated 28% of the total radio traffic across the 4 networks, with 793 transmissions.

The SC communicated about 54% of the total transmissions, and the 2IC generated about 47% of the total transmissions on this network.

Table 11: Network 1 – Traffic by role

	SC	2IC	Total
Total	427	366	793
% of Total	54%	47%	

It is also important to consider the types of communication initiated by the SCs and the 2IC's. This is shown in Figure 14.

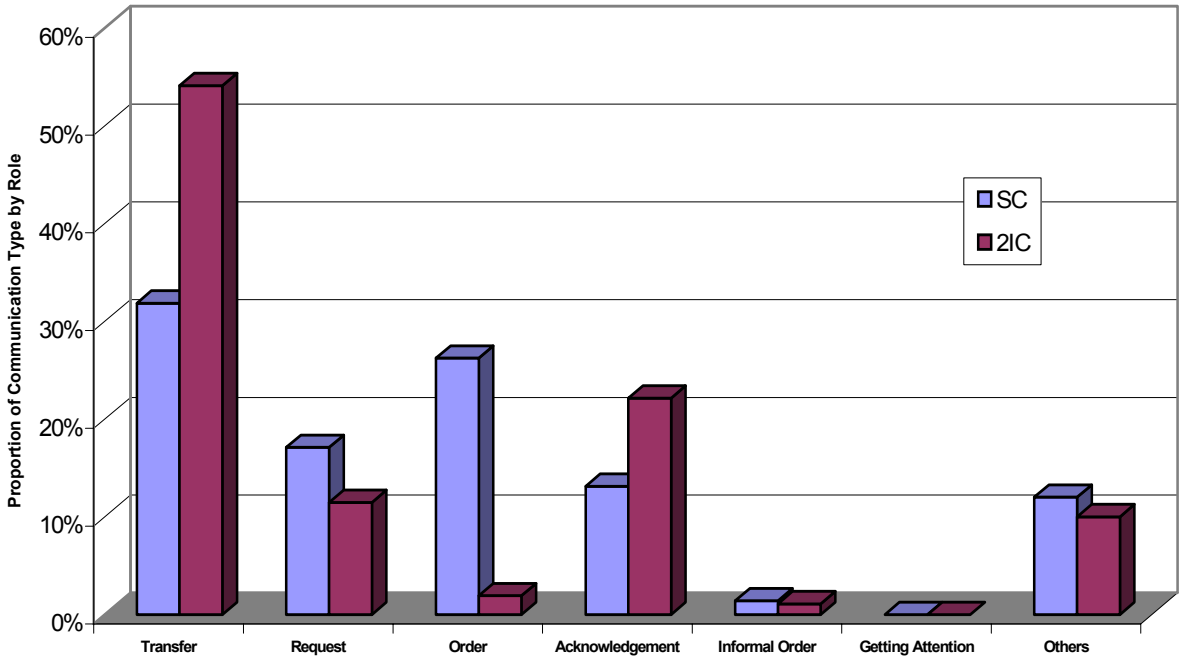


Figure 14: SC and 2IC network - Type of communication by role

As Figure 14 shows, the SC was more active than the 2IC in orders and requests. In fact, SC maintained the lead role on this network, with 26% of the SC's transmissions being orders. The 2IC, on the other hand, used only 2% of his transmissions to give orders. Instead, as evidenced by the high proportion of transfers, 2IC's devoted the majority of their communication efforts toward informing the SC.

4.3.2 Network 2 – SC's AG Network (4)

About 31% of the total transmissions were attributable to the SC's AG network. As the table below shows, 58% of the traffic on the SC's AG network was accounted for by transmissions from the SC to the members of his AG.

Table 12: Network 2 – Traffic by role

Radio Network 2	SC	AG Members	Total
Total	518	278	896
% of Total	58%	42%	

As Figure 15 shows, orders given by the SC represented the most important type of communication within this group, accounting for more than 60% of the total transmissions.

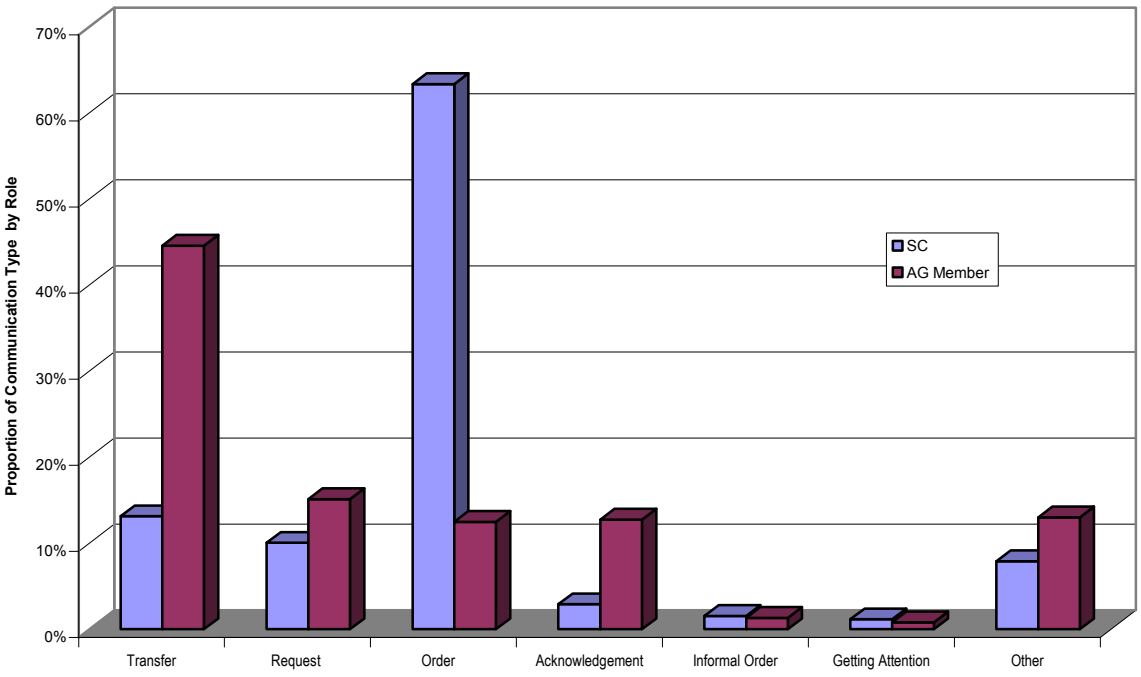


Figure 15: SC AG - Type of communication by role

Again, the graph indicates that SC remained in charge, while AG members primarily transferred information to the SC.

4.3.3 Network 3 – 2IC's AG Network (4)

This network had the highest frequency of transmissions compared to the other three networks. The highest proportion of traffic was generated by the 2IC, at almost 63% with only 37% distributed among the rest of the AG members.

Table 13: 2IC's AG – Traffic by role

	2IC	AG Members	Total
Total	599	353	952
% of Total	63%	37%	

As depicted in the chart below, the 2IC uses orders as the major type of communication, accounting for almost 60% of his total communications.

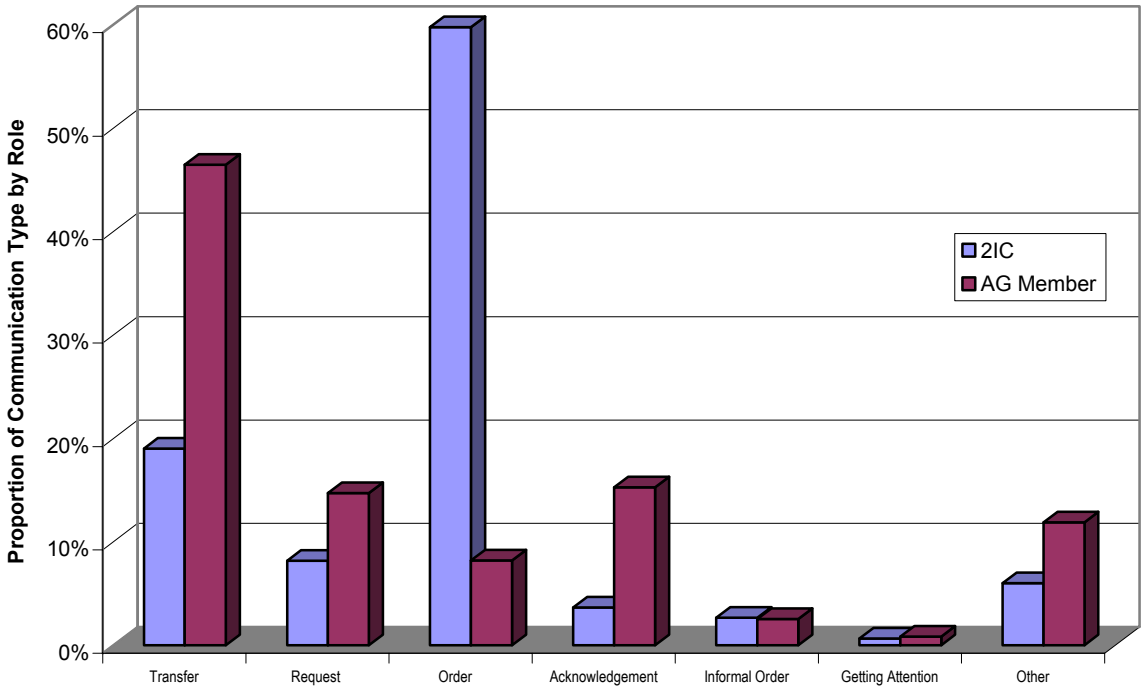


Figure 16: 2IC AG - Type of communication by role

Transfers are the second most important form of communication for the 2IC, but much lower when compared to the AG members. AG members communicate more requests and acknowledgements than the 2IC.

Although there are minor differences in the distribution of types of communication used, this analysis suggests that the 2 AGs, despite their leaders, used very similar patterns of communication.

4.3.4 Network 4 - All section members network (8)

Network 4 was the least used network of the four at less than 5%. In terms of who was using the network, AG members generally were the most frequent users, at 45% of all transmissions, with SC's at 43% of transmissions, and 2IC's at 13% of the total communications on this network.

Table 14: Network 4 – Traffic by role

	SC	2IC	AG members	Total
Total	77	23	81	181
% of Total	43%	13%	45%	100%

The proportion of transfers within this network is similar to that within the separate AG. Unlike the separate AG networks, however, this common network appears to have been used somewhat less often for orders, but somewhat more often for requests.

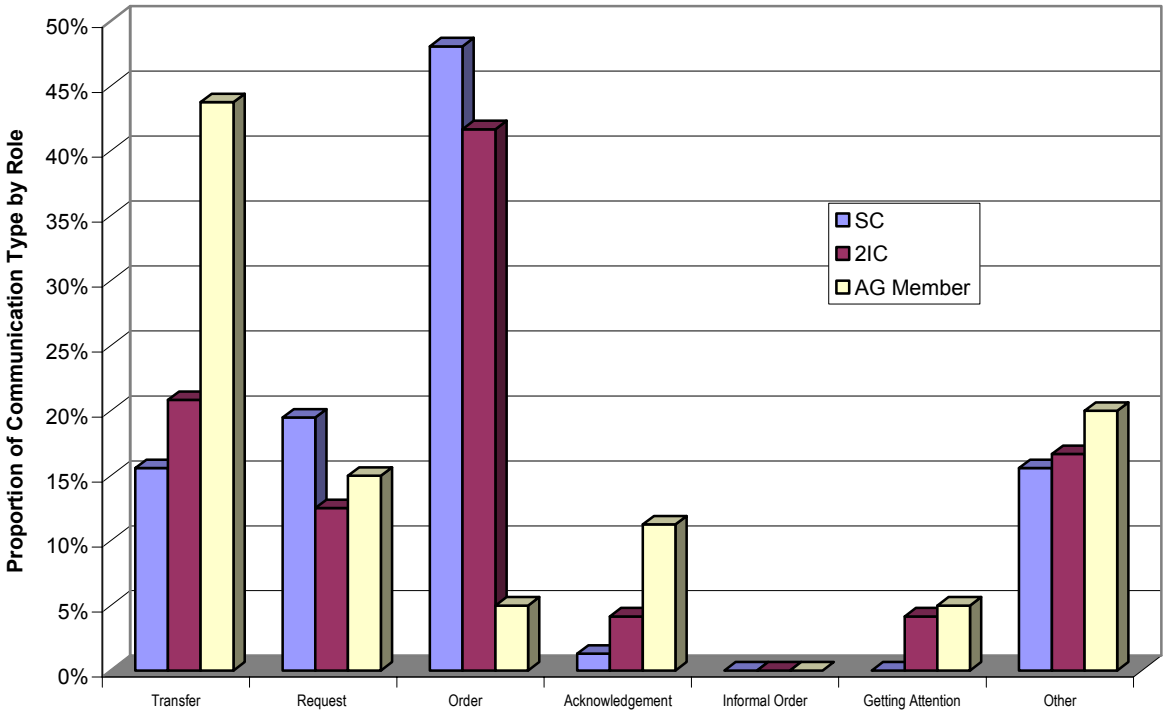


Figure 17: All section members network - Type of communication by role

Looking at how people within the various roles of the AGs used their communications, the chart above shows the proportion of each type of communication by role. Again, the SC and the 2IC focus their communications on orders, with the AG members transferring information. The groups appear to be most evenly distributed in their frequencies of transmissions concerning requests, with SC's and members making slightly more requests than 2IC's.

Summary: The high rate of communication between the SC and 2IC appears to indicate a preference for the SC and the 2IC to plan the movement of each AG between themselves prior to execution. Moreover, each leader transmitted this information on their own AG networks rather than working out their plans on the all-members net. The sparse use of the all-members net, and, in fact, the request to "stay off comms" seemed to indicate that the AG leaders preferred to maintain control of the airwaves.

4.4 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 1.6 indicates that a team's transfers exceeded their requests, 1.6 to 1. A ratio of 1.0 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.

It is important to compare whether AG show different patterns of anticipatory communication as a result of having radio communication. Anticipation ratios were calculated for each of the radio networks, as well as for the No Radio condition, and are presented in the table below.

As can be seen from the table, the ratio of transfers to requests was much higher when teams did not have radios, as requesting information was very rare. When a section did have radio communication, the anticipation ratio was 2.5.

Table 15: Anticipation ratios by condition

	Radio	No Radio
Transfers	900	69
Requests	356	2
Anticipation Ratio	2.5	34.5

As the following table shows, there was diversity within the radio communication networks, with the SC and 2IC network being the richest in anticipation, at a ratio of 2.9, although this ratio was close to that of the 2IC AG network, which was 2.8. The all-member net had the lowest proportion of transfers to requests, at a ratio of 1.7.

Table 16: Anticipation ratios by radio network

Radio	SC and 2IC	SC Assault Group	2IC Assault Group	All-members Network
Transfers	334	236	278	52
Requests	115	110	101	30
Anticipation Ratio	2.9	2.1	2.8	1.7

Lastly, the table below shows the anticipation ratios within the AG roles. The SC's rate was relatively low at 1.5, as the major function of this leader was to give orders, not to transfer information. The 2IC, on the other hand, showed a much higher rate with 3.4 transfers for every 1 request. AG members also showed a high anticipation ratio at 3.0.

Table 17: Anticipation ratios by role

Radio	SC	2IC	AG member
Transfers	216	317	367
Requests	140	94	122
Anticipation Ratio	1.5	3.4	3.0

This pattern of results supports the view that having radios improves intra-section communication by making it more evenly balanced and diverse.

4.5 Outcome Measures

Outcome measures included team performance and team process. The former includes measures such as rounds taken, rounds fired, and AG deaths (occurring because of improper use of grenades). Team process includes measures of status awareness, teamwork, and workload.

4.5.1 Team Performance

One of the possible advantages of having radio communications is an improvement in team performance. One might expect missions in which section members have radio communication to be more effectively and/or efficiently performed. Within the context of tactical assault missions, rounds taken, rounds fired, and AG deaths are indirect indicators of team performance. Analyses were conducted to explore section performance with and without radio communications.

Casualties (Rounds Taken): Data on the number of hits sustained by each member and the AG, as a whole, was recorded.

In the Radio condition, a total of 1182 rounds were taken by AGs as a whole, with a mean of 11.6 rounds taken by each person in each mission. The number of rounds taken ranged from 0 to 126 rounds taken.

In the No Radio condition, a total of 771 rounds were taken by members of the AG, with a mean of 7.1 rounds taken by each person in each mission. The number of rounds taken ranged from 0 to 74.

Table 18: Rounds taken by condition

Mean (StDev)	Radio	No Radio	Sig. Differences
Rounds Taken	12.0 ± 23.6	7.1 ± 15.1	bs

Comparisons of the number of rounds taken by soldiers in the Radio and No Radio conditions were completed for each AG. In short, there was no difference in rounds taken with a radio or without.

Ammunition Use (Rounds Fired): The number of rounds expended by the section as a whole was recorded.

Within the Radio condition, the total number of rounds expended was 3243 with an average of 30.9 rounds expended by each person on each mission. Rounds fired within a given mission ranged between 0 and 177.

Within the No Radio condition, the total number of rounds expended was 2896 with an average of 26.3 rounds expended by each person on each mission. Rounds fired within a mission ranged between 0 and 172.

Table 19: Rounds fired by condition

Mean (StDev)	Radio	No Radio	Sig. Differences
Rounds Fired	30.9 ± 40.0	26.3 ± 37.6	ns

Comparing the number of rounds expended in the Radio vs. the No Radio conditions showed no differences overall in the rounds fired.

Deaths: An analysis was also conducted on the number of AG member deaths within the 2 conditions, with the frequencies shown in Table 20 (coded as dichotomous data for this analysis). This test showed no significant difference in the frequency of deaths with and without a radio.

Table 20: Number of deaths by condition

Frequency	Radio	No Radio	Sig. Differences
Deaths	16	14	ns

Summary – The results of these analyses indicated that (at least for these measures of performance), having radio communications did not markedly improve team performance. Although teams transmitted much more information with the addition of a radio, and were able to anticipate information needs fairly proficiently, this knowledge did not result in improved performance in the Radio condition.

It is important to note a number of caveats here. The rounds fired measure, for example, may have been influenced by a technical glitch that made it extremely difficult for gunners to kill the enemy. The enemy was configured to die after only 1 or 2 rounds. Moreover, the fact that some AG members changed their tactical strategy once they realized that they were invincible may have also influenced both the rounds fired and the rounds taken measures. It seems important for future work to address the lessons learned during this pilot study, and to also work on refining measures of performance outcome in order to yield even finer measures of mission performance.

4.5.2 Team Process

Another possible advantage of having radio communications is improvement in team processes. One might expect team processes, such as status awareness, teamwork and workload, to be better with radio communication.

Status Awareness: Providing radio communications has the potential to enhance the status awareness of section members. Radios provide an easy conduit for information, and such information may increase awareness of one's own AG, and a better sense of one's own AG timings.

At a critical stage of the mission (e.g. immediately following an engagement with the enemy), the game server was paused and soldiers indicated their awareness of the casualties, timings, and

position of both their own AG and the other AG, using a 4 point scale ranging from 0 (not at all) to 4 (very).

Table 21: Status awareness

Mean (StDev)	Radio	No Radio	Sig. Differences
Awareness of other casualties	0.3 ± 0.5	0.3 ± 0.6	ns
Awareness of other timings	2.1 ± 0.6	2.2 ± 0.5	ns
Awareness of own timings	2.1 ± 0.4	2.1 ± 0.4	ns

As depicted above, having a radio did not significantly enhance soldiers' status awareness. They indicated that they were relatively unaware of other casualties across conditions. However, they indicated that they were relatively aware of mission timings in both the Radio and No Radio conditions. It is possible that soldiers were concentrating more on how to use the radio at this stage, than what aspects of the game the radio was helping them with. The findings concerning workload (in a later section) may speak to this issue. We would expect that if the above explanation is true, then soldiers would either experience more workload with the radio, or at least as much workload than without one.

Teamwork: Soldiers completed a teamwork questionnaire (see Appendix A) 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. This questionnaire included 14 items, and soldiers used a 7-point scale, ranging from 1 (strongly disagree) to 7 (strongly agree) to rate these items (see Appendix A).

Overall, soldiers seemed to have fairly positive impressions of their AG working together as a team, with an overall mean of 5.4 out of 7. As shown in Table 22, overall perceptions of teamwork were not significantly different when teams had a radio than when they did not have radio communication, $t(95) = -.46$, $p = .13$.

Table 22: Teamwork

Mean (StDev)	Radio	No Radio	Sig. Differences
Teamwork Index	76.0 ± 15.3	74.3 ± 14.3	ns

Workload: Soldiers also completed a NASA TLX questionnaire (see Appendix A), indicating the levels of subjective workload experienced during the mission. This version of the NASA TLX requires the participant to rate six measures of mental workload on an 18-point scale ranging from high (18 represents demanding, complex) to low (1 represents easy, simple). Items including mental demand, physical demand, temporal demand, task performance, effort, and frustration were averaged to form a single workload index.

Table 23: Workload

Mean (StDev)	Radio	No Radio	Sig. Differences
Workload Index	38.4 ± 20.0	34.0 ± 19.2	R>NR $t(94)=2.8$

Soldiers indicated that they experienced significantly more workload in the Radio condition than the No Radio condition. One might expect that as communication within teams is generally argued to be positive, when performing with a radio, one might expect for section members to experience less mental, physical, and temporal demand. This was not the case. The overall perception of increased workload in the Radio condition may be related to the sheer volume of communication during the missions where soldiers carried a radio. In the focus groups, soldiers agreed that perhaps due to the novelty of the new communication devices, strict radio discipline was not always observed. Soldiers did not have SOP regarding radio communications. Moreover, responding, or even just listening to repeated communication, may have been taxing.

Summary: There were no differences in perceived status awareness or teamwork. The significant increase in perceived workload in the Radio condition suggests that soldiers needed to expend greater cognitive resources when using the radio. However, more practice with the radio and the development of SOP for radio communications in general might reduce overall workload. In other words, once the use of the radio becomes less directed and effortful and more automatic, focus on the communications might be attenuated, freeing up cognitive resources and allowing more broad attention to the super-ordinate tasks, such as teamwork toward mission success.

4.6 Exit Questionnaire and Focus Group

At the end of the missions, participants completed an exit questionnaire (see Appendix A) and participated in a focus group. Researchers were interested in identifying soldiers' overall perceptions regarding the benefits and drawbacks of the radio communications and the perceived impact of radios on information transfer, coordination and awareness within and between AG. Researchers were also interested in identifying participants' overall perceptions of the experimental approach and the use of the 1st Person gaming environment. Soldiers were asked to rate questionnaire items using the seven-point Likert scale where 1 represented "Completely Unacceptable" and 7 represented "Completely Acceptable".

Information Transfer – Soldiers also completed two sets of rating scales assessing acceptability of the radio systems for transfer of information using either the radio communication system, or using current operational procedures (i.e. without enhanced communication capabilities).

Table 24: Information transfer

Mean (StDev)	Radio	No Radio	Sig. Differences
Amount of information passed	6.4 ± 0.7	3.9 ± 1.4	R>NR, t (11)=5.0
Time required to pass information	6.3 ± 0.9	4.3 ± 1.9	R>NR, t (11)=3.4
Timeliness for initiating communications	6.4 ± 0.8	4.4 ± 1.6	R>NR, t (11)=3.6
Ease of passing information	6.5 ± 0.7	3.7 ± 2.1	R>NR, t (11)=5.5
Ease of passing information within AG	6.5 ± 0.7	4.0 ± 1.7	R>NR, t (11)=5.5
Ease of passing information within section	6.4 ± 0.8	3.7 ± 1.7	R>NR, t (11)=6.4
Ease of getting acknowledgement of information received	6.2 ± 0.7	3.2 ± 1.7	R>NR, t (11)=5.6
Ease of getting acknowledgement of information understood	6.3 ± 0.7	3.7 ± 2.0	R>NR, t (11)=4.1
Accuracy of information passed	6.4 ± 0.7	3.9 ± 2.1	R>NR, t (11)=3.8
Message detail possible	6.3 ± 1.2	3.4 ± 2.2	R>NR, t (11)=3.5

As outlined in Table 24, all aspects of information transfer were rated as more acceptable with radio than without.

Coordination and Awareness Within and Between Assault Groups: In theory, having radio communications may also impact on the ability of section members to coordinate their actions, and to have high status awareness given the potential increase in information. Moreover, whether section members are working to communicate within their specific AG, or with AG approaching the enemy objective from a different route, coordination and awareness are likely to be higher both within and between AG. Soldiers' ratings of overall coordination within their AG in the Radio and No Radio conditions are presented in the table below.

Table 25: Coordination within AG

Mean (StDev)	Radio	No Radio	Sig. Differences
Coordination of movement	6.6 ± 0.5	4.0 ± 1.4	R>NR, t (11)=5.7
Coordination of fire	6.3 ± 0.9	3.8 ± 1.6	R>NR, t (11)=4.4
Coordination of action	6.2 ± 0.9	3.5 ± 1.9	R>NR, t (11)=4.5
Issuing/receiving orders	6.6 ± 0.7	3.4 ± 1.7	R>NR, t (11)=6.9
Designating targets	6.8 ± 0.5	3.3 ± 1.9	R>NR, t (11)=6.1
Ease of distributing message within AG	6.3 ± 0.8	2.9 ± 1.8	R>NR, t (11)=7.3
Awareness of location of your AG members	6.1 ± 1.0	3.6 ± 1.6	R>NR, t (11)=4.2
Awareness of casualties of your AG members	6.0 ± 1.0	2.8 ± 1.9	R>NR, t (11)=5.3
Awareness of casualties of other AG members	5.9 ± 1.7	2.3 ± 1.4	R>NR, t (11)=7.4
Awareness of ammunition usage of your AG members	5.4 ± 2.0	2.8 ± 1.7	R>NR, t (11)=2.7

As this table clearly shows, having a radio improves the coordination within AGs.

Similar results were evidenced between AGs. Again, abilities to perform all of the necessary coordination and awareness activities were rated as more acceptable with a radio than without.

Table 26: Coordination between AG

Mean (StDev)	Radio	No Radio	Sig. Differences
Coordination of AG movement	5.7 ± 1.0	2.8 ± 1.3	R>NR, t (11)=6.5
Coordination of Section fire	6.0 ± 10	2.9 ± 1.7	R>NR, t (11)=4.5
Coordination of Section action	6.0 ± 0.9	2.9 ± 1.4	R>NR, t (11)=6.6
Issuing/receiving orders	6.0 ± 1.0	3.2 ± 1.6	R>NR, t (11)=5.8
Designating targets	5.9 ± 1.7	2.8 ± 1.6	R>NR, t (11)=6.3
Ease of distributing message within Section	6.1 ± 0.9	2.6 ± 1.4	R>NR, t (11)=10.2
Awareness of the location of the other AG	6.0 ± 1.4	2.1 ± 1.4	R>NR, t (11)=6.6
Awareness of casualties of the other AG	6.3 ± 0.7	2.2 ± 1.3	R>NR, t (11)=9.5
Awareness of ammunition usage of the other AG	6.0 ± 1.0	1.8 ± 1.1	R>NR, t (11)=10.3

Soldiers rated their ability to work between assault groups better with the radio than without, suggesting that radios facilitate the co-ordination both within and between AGs.

Lastly, soldiers also responded to several statements about the communications system and about the experiment in general.

Table 27: Soldiers' level of agreement with radio comms

General Statements (n = 12)	Mean (StDev)
Game behaviour same as in real mission	4.3 ± 2.3
Required more training to become effective in game simulation	4.0 ± 2.1
With radio communication, my assault group was more effective as team	6.2 ± 1.7
All members of dismounted infantry should have radio communication	5.1 ± 1.2
More aware of situation with hand signal than with voice	3.0 ± 2.1
Voice comms preferred over no voice comms	5.1 ± 1.3
AG C2 were improved with voice comms	6.3 ± 0.8
Section C2 were improved with hand-signal system	2.9 ± 1.8

Soldiers agreed that their game behaviour was fairly realistic, but that they could have used more training. They also agreed overwhelmingly that they were more effective as a team with radio comms, and most agreed that all members should have comms.

Although soldiers rated the communication system highly, there was no consensus during the focus groups that all members of an AG should necessarily have access to radio communication. In fact, soldiers were almost equally split on this issue. Some argued that having radio communication capability would greatly aid AGs on their missions. Those who disagreed believed that radio communications were useful, but argued that only the leaders of AGs should have them. They mentioned that the traffic generated by all members of the team having radios created too much traffic, with too little bandwidth left for critical and time urgent communication between leaders.

Software Realism: Soldiers rated the realism of the software simulation on a variety of dimensions, including the terrain and surroundings, the weaponry, and the actions of their computer avatars. Ratings were again completed on a 7-point scale, ranging from 1 (completely unacceptable) to 7 (completely acceptable). Results are presented in Table 28.

Table 28: Perceived software realism

Software Realism (n = 12)	Mean (StDev)
Terrain	6.3 ± 0.5
Buildings	6.2 ± 0.6
Lighting	6.3 ± 0.8
Weather	6.2 ± 1.0
Weapons Use	6.1 ± 1.0
Weapons Effects	5.8 ± 1.1
Clothing/Equip	6.6 ± 0.5
Own Actions	5.9 ± 0.7
Actions of other friendlies	6.2 ± 0.7
Action of other enemies	6.0 ± 0.6

Results show that soldiers were generally quite impressed with the realism of the software, of the environments through which they navigated, with the weapons and equipment that they used, and with the actions and movements of their computer avatars. The two lowest ratings (still rated more than acceptable) were the weapons effects, and the actions of soldiers' own computer avatars.

These issues were explored in more detail in focus group discussions. The major problem with weapon realism was in the use of grenades. As noted earlier, throwing grenades in the game differs from reality because of the inability to deliberately bend the computer avatar's arm. Consequently, this limitation prevented throwing a grenade accurately around a corner. Some soldiers also noted a bigger problem with an unrealistic grenade blast that could cause death even when standing behind concrete walls. A more generic concern that the grenade kill zone was too large was also expressed. These issues, then, seem to underlie the lower ratings on weapon effect and action of one's own computer avatar. Nonetheless, as a whole, the software simulation was given very high ratings, and did seem to have encouraged immersion and engagement in the test environment.

Communications System – The communications system as a whole was given high marks as well, with audio quality, microphone quality and ease of use all being rated highly at more than 6 out of 7.

Table 29: Perceived acceptability of communication system

Communication system (n = 12)	Mean (StDev)
Audio quality	6.8 ± 0.4
Microphone quality	6.8 ± 0.4
Ease of intercom use	6.0 ± 1.4

In general, soldiers reported few problems learning to use the radio system, and generally found it reliable whenever they wanted to communicate with their team. The only potential problem was in coordinating the use of the computer avatar (which required having one's hands on the keyboard) while attempting to reach the intercom button in order to initiate communication. This was more of a problem, of course, when under direct enemy contact.

4.7 Limitations

The composition of the AG, and their relative inexperience, may have implications for the generalizability of this pilot study. As the members were relatively inexperienced in real urban operations, the results (e.g. the communication patterns) and the processes used to coordinate the assault may have been different, than if they had previous experience in operations and with each other. The relative inexperience of the soldiers may have been related to a lack of proper radio voice procedure (e.g. SOP), evident during both mission completion and expressed during the exit focus group. Soldiers (particularly the AG leaders) expressed concern about communication on the radio networks they perceived to be unnecessary. Whatever limitations on the generalizability of the study the sample of soldiers may impose, however, the soldiers did prove an interested and motivated set of individuals who helped to chart the first steps of understanding the impact of providing radio capabilities within infantry sections.

5. Discussion

The purpose of the present study was to determine whether the addition of a radio improved various aspects of simulated tactical assault missions, including team performance and team process. Currently, soldiers in the CF do not have the benefit of radios, but soldier modernization programs in other nations have shown a trend toward using radios. It seems intuitive that radios would improve at least some aspects of communication and performance within the context of a mission.

The first aim of this study was to explore the frequencies of types and functions of communication with and without radios. We found that section members communicated about 10 times more often with radios than without. When they did not have a radio, the most frequent type of communication was orders, followed by transfers of information. There were almost no requests for information or acknowledgements. When they did have radios, this pattern of frequency was still evidenced. However, the difference between the frequency of orders and the frequency of transfers of information was much smaller, and there was a rise in the number of requests for information and acknowledgements. It appears that when infantry sections have radios, the type of communication that they use is more varied and differentiated. There were also similar patterns across conditions in the functions of communication. In both conditions, the primary function of communication was related to location, followed by status. However, in the Radio condition, there were fewer communications related to location and more related to status compared to the No Radio condition. It seems that when they do not have radios, much of the time is spent keeping others informed about location, but there is little concern or chance for asking questions or getting clarification. There was no difference in the duration of messages between the Radio and No Radio conditions, but information was slightly more elaborated in the former.

With regard to communications within roles, in both conditions, the SCs and 2ICs generated much of the communication. However, communication was more evenly distributed over roles when soldiers had a radio. Indeed, AG members communicated approximately twice as often in the Radio condition than the No Radio condition. In general, SC's most common type of communication in both conditions was the order, followed by transfers. The SCs included requests in their communications in the Radio condition where they did not in the No Radio condition. Regarding the type of communication from 2IC's, a similar pattern held for them as it did for the SC. With respect to AG members, however, the Radio condition showed a substantial decrease in orders and an increase in both requests and acknowledgements. Transfers of information, on the other hand, remained consistently high in both conditions for AG members.

These findings may indicate that section members assume different types of duties and responsibilities with and without a radio, and that they feel increased empowerment when they have radios. It is also possible that, with radios, they are better able to communicate what their actual needs are, creating greater accuracy in communication. For example, it is possible that because AG members made about one-quarter the number of orders in the Radio condition than the No Radio condition, they were forced to communicate orders when they really wanted to communicate something else. In this sense, they may have been using an order to accomplish other purposes, such as requests. By observing their teammates behaviours surrounding their order, they could gain information they wanted in a necessarily indirect way. We might say,

then, that radios allow for more accurate communication in comparison to hand signals, not just because hand signals have restrictions and restraints in order to be effective, but because radios allow a wider range of direct communications.

The second aim was to compare differences in communication with and without radios across four networks. Results indicated that the most frequent communication occurred among the members of the two 4-person AGs, followed by the leader network, then the all section members network. AG members reserved most of their communications for their small group. It is likely that the information they were communicating was more relevant to members of the small group. Further, AG members may not have had much of an inclination to speak, restricting themselves to typical and necessary communication responses. The leaders, on the other hand, spoke often on the private leader net and their own AG net in order to plan and execute the missions.

Regarding outcome measures, the addition of a radio did not improve any objective aspect of the soldier's performance, such as rounds taken, rounds fired, and the frequency of assault group member deaths. Recall that due to the parameters embedded in the game software, soldiers frequently killed themselves and the rest of their team accidentally with grenades. Thus, it will be necessary to control deaths from friendly fire in future research, possibly through the use of smoke grenades and flash bangs. With respect to team process, the introduction of a radio did not increase soldiers' perception of status awareness and teamwork, though there was an increased perception of workload among participants. These findings regarding team process could be the result of soldiers' lack of radio SOP, leading to high communication traffic. Perhaps once soldiers became accustomed to the radio and game, their performance would improve and they would perceive positive changes to performance and process correlates.

In contrast, the exit focus groups indicated overwhelming support for the use of radios. Soldiers did indicate that their perceived overall awareness of their surroundings and the conditions of their teams, and their co-ordination within and between AGs's were improved with the radio. Moreover, soldiers indicated that Rogue Spear provided a great deal of realism which engendered immersion in the game. The only pervasive complaint was that the grenades were not realistic in several respects including lengthy activation, lack of de-activation, aiming difficulty, and they could explode through walls, killing one's team. Their caveats about the use of radios centered on security issues (e.g. could they be intercepted by enemy?) and which members of a section should have them. Concern was expressed that if everyone had access, it might tie up the lines for important communications between the SC and 2IC. Some soldiers suggested that the SC and 2IC could have interrupt capability. Soldiers also felt that radios might give each individual too much power, and that soldiers may come to rely too heavily on the comms promoting laziness and carelessness.

In conclusion, this pilot study suggests that radios are desirable to soldiers engaging in computer-generated tactical assault missions. Future research should seek to refine and optimize the cognitive and physical task requirements for radio operation, and test their use in field trials, keeping in mind that soldiers will probably experience increased workload until the task becomes rote. Additional research should also continue to examine the most desirable network configuration(s). The fact that location was the most frequent function of communication suggests that future studies should also examine the location function in more detail, possibly considering the use of individual digital maps.

6. References

Entin, E.B., Entin, E.E., MacMillan, J., and Serfaty, D. (1993). Structuring and Training High Reliability Teams. U.S. Army Research Institute (Technical Report-599).

Sperry, D. (1995). Distinguishing the Communication and Coordination Differences Between Superior and Good Teams in Tactical Scenarios. Naval Postgraduate School, Monterey, CA.

Annex A: Questionnaires

Personal Information Questionnaire

Please provide the requested personal information in the spaces provided:

1. JOB DETAILS:

MOC	Rank					
	Pte ○	Cpl/MCpl ○	Sgt/WO ○	MWO/CWO ○	Jnr Offr ○	Snr Offr ○
Unit Abbreviation	**Sub-Unit** (e.g. B Coy)			**Job Title** (e.g. C9 Gunner, Medic, Signaller)		

2. LAND FORCE EXPERIENCE:

Length of Service			
0 – 1 Year ○	1 – 5 Years ○	5 – 10 Years ○	Over 10 Years ○
Operational Experience (By Theatre) ***(more than one selection is permitted)***			
Middle East ○	Golan Heights ○	Sinai ○	Croatia ○	Bosnia ○	Rwanda ○
Cyprus ○	Somalia ○	Cambodia ○	Haiti ○	Kosovo ○	Other ○
Skills			
Rate your planning skills			
Terrible ○	**Poor** ○	**Fair** ○	**Good** ○	**Excellent** ○	
Rate your map reading skills			
Terrible ○	**Poor** ○	**Fair** ○	**Good** ○	**Excellent** ○	

Rate your hand signal communication skills				
Terrible	**Poor**	**Fair**	**Good**	**Excellent**
○	○	○	○	○
Rate your tactical movement skill				
Terrible	**Poor**	**Fair**	**Good**	**Excellent**
○	○	○	○	○
Rate your target engagement skill				
Terrible	**Poor**	**Fair**	**Good**	**Excellent**
○	○	○	○	○
Experience				
Rate your training and/or operational experience planning missions.				
None	**Some**	**Moderate**	**Extensive**	
○	○	○	○	
Rate your training and/or operational experience conducting Section assaults.				
None	**Some**	**Moderate**	**Extensive**	
○	○	○	○	
Rate your training and/or operational experience using maps.				
None	**Some**	**Moderate**	**Extensive**	
○	○	○	○	
Rate your training and/or operational experience in urban operations.				
None	**Some**	**Moderate**	**Extensive**	
○	○	○	○	
Rate your experience using 1st Person Shooter computer games.				
None	**Some**	**Moderate**	**Extensive**	
○	○	○	○	

Status Awareness

PARTICIPANT NUMBER : _____ MISSION NUMBER : _____

ASSAULT GROUP : _____ SECTION NUMBER : _____

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

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

Answer the following questions by filling in the appropriate circle.

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

Casualties: None ○ Light ○ Moderate ○ Heavy ○

Timings: Very Early ○ Early ○ On-time ○ Delayed ○ Very Delayed ○

2. Indicate YOUR timing status for linking up with the other Assault Group at the objective.

Timings: Very Early ○ Early ○ On-time ○ Delayed ○ Very Delayed ○

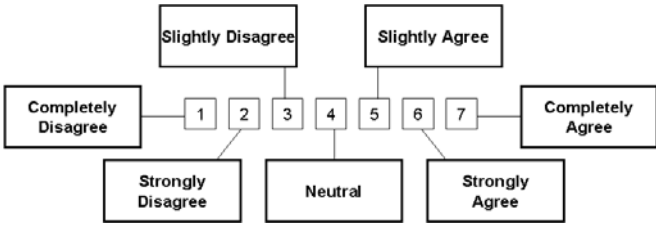
Teamwork

PARTICIPANT NUMBER : _____

MISSION NUMBER : _____

ASSAULT GROUP : **_____**

SECTION NUMBER : _____



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

MAP CONDITION: **MAP** ○ **NO MAP** ○

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

SECTION A: Rate the degree to which you agree with the following statements using the scale provided. Please consider your responses to these scales carefully:	**Agreement with Statement**						
	Strongly Disagree			**Neutral**			**Strongly Agree**
	1	**2**	**3**	**4**	**5**	**6**	**7**
My assault group coordinates well in completing this mission.	○	○	○	○	○	○	○
My assault group leader provides good direction in helping our assault team to meet this mission's goals.	○	○	○	○	○	○	○
During this mission, my team members are able to anticipate my actions and I am able to anticipate theirs.	○	○	○	○	○	○	○
Teamwork increases to our assault group's ability to complete this mission.	○	○	○	○	○	○	○
During this mission, my assault team members have failed to give me the information that I need to make decisions.	○	○	○	○	○	○	○
Our assault team shows a poor level of cooperation during this mission.	○	○	○	○	○	○	○
In this mission, my assault group and I work well as a team.	○	○	○	○	○	○	○

SECTION A: Rate the degree to which you agree with the following statements using the scale provided. Please consider your responses to these scales carefully:	**Agreement with Statement** **Strongly Disagree** — **Neutral** — **Strongly Agree** **1** **2** **3** **4** **5** **6** **7**
Our assault group is able to accomplish more as a team than as individuals.	○ ○ ○ ○ ○ ○ ○
I am <u>not</u> confident in the abilities of my teammates during this mission.	○ ○ ○ ○ ○ ○ ○
The members of my assault team have a common view of how to complete this mission.	○ ○ ○ ○ ○ ○ ○
In general, my assault group works well as a team.	○ ○ ○ ○ ○ ○ ○

SECTION B: COMMENTS

Mission Questionnaire

PARTICIPANT NUMBER : _____ MISSION NUMBER : _____

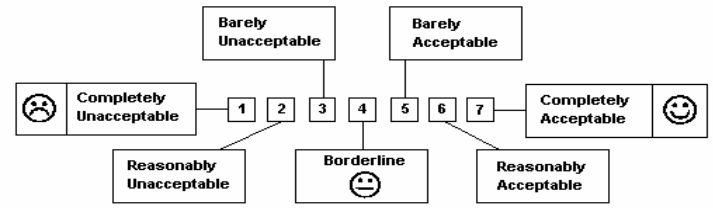
ASSAULT GROUP : _____DAY / NIGHT SECTION NUMBER : _____

RADIO CONDITION: RADIO ○ NO RADIO ○

MAP CONDITION: MAP ○ NO MAP ○

ROLE: RIFLEMAN ○ 2IC ○ SECTION COMD ○

USING THE SCALE PROVIDED, INDICATE THE ACCEPTABILITY OF THE FOLLOWING ASPECTS OF YOUR MISSION.



INFORMATION TRANSFER	☹			😐			☺
	1	**2**	**3**	**4**	**5**	**6**	**7**
Timeliness for initiating comms	○	○	○	○	○	○	○
Time needed to pass information	○	○	○	○	○	○	○
Ease of passing information	○	○	○	○	○	○	○
Accuracy of information passed	○	○	○	○	○	○	○
WITHIN ASSAULT GROUP	☹			😐			☺
	1	**2**	**3**	**4**	**5**	**6**	**7**
Coordination of movement	○	○	○	○	○	○	○
Coordination of fire	○	○	○	○	○	○	○
Coordination of action	○	○	○	○	○	○	○
Issuing / Receiving orders	○	○	○	○	○	○	○
Designating targets	○	○	○	○	○	○	○
Sharing information	○	○	○	○	○	○	○

SITUATION AWARENESS	☹			😐			☺
	1	**2**	**3**	**4**	**5**	**6**	**7**
Awareness of YOUR location	○	○	○	○	○	○	○
Awareness of location of YOUR Assault Group members	○	○	○	○	○	○	○
Awareness of casualties among YOUR Assault Group members	○	○	○	○	○	○	○
Awareness of ammunition usage of YOUR Assault Group	○	○	○	○	○	○	○
Awareness of the mission terrain	○	○	○	○	○	○	○
Awareness of Enemy location	○	○	○	○	○	○	○
Awareness of Enemy status	○	○	○	○	○	○	○
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	○	○	○	○	○	○	○
WITHIN THE SECTION	☹			😐			☺
	1	**2**	**3**	**4**	**5**	**6**	**7**
Coordination of Assault Group movement	○	○	○	○	○	○	○
Coordination of Section fire	○	○	○	○	○	○	○
Coordination of Section actions	○	○	○	○	○	○	○
Risks of Friendly fire	○	○	○	○	○	○	○
MISSION	☹			😐			☺
	1	**2**	**3**	**4**	**5**	**6**	**7**
Teamwork	○	○	○	○	○	○	○
Tempo of mission	○	○	○	○	○	○	○
Ability to make mission timings	○	○	○	○	○	○	○
Ability to maintain stealth	○	○	○	○	○	○	○
Ability to adapt to unexpected changes in mission	○	○	○	○	○	○	○
Total casualties	○	○	○	○	○	○	○
Mission effectiveness	○	○	○	○	○	○	○
OVERALL ACCEPTANCE	○	○	○	○	○	○	○

Comments

Workload Questionnaire

NAME : _____ MISSION NUMBER : _____

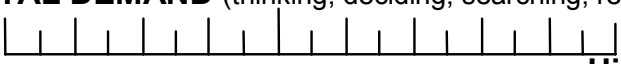
ASSAULT GROUP : _____ SECTION NUMBER : _____

CONDITION: VOICE ☐ NO VOICE ☐

ROLE: RIFLEMAN ☐ 2IC☐ SECTION COMD ☐

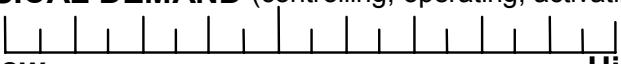
Section A: Rate the trial by marking each scale at the point which matches your experience. Each line has two endpoint descriptors to help describe the scale. Please consider your responses to these scales carefully.

MENTAL DEMAND (thinking, deciding, searching, remembering)



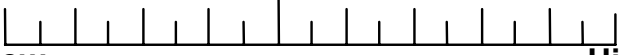
Low (easy, simple) **High** (demanding, complex)

PHYSICAL DEMAND (controlling, operating, activating)



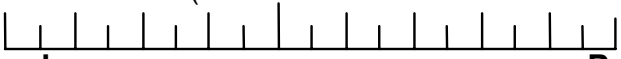
Low (easy, restful) **High** (demanding, laborious)

TEMPORAL DEMAND (time pressure)



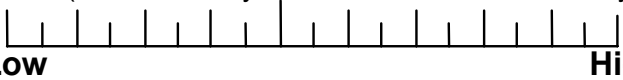
Low (leisurely) **High** (frantic)

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



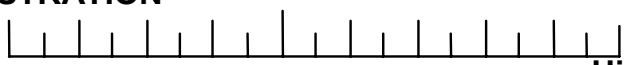
Good **Poor**

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



Low **High**

FRUSTRATION



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

Section B: Comments (Use back of page if required)

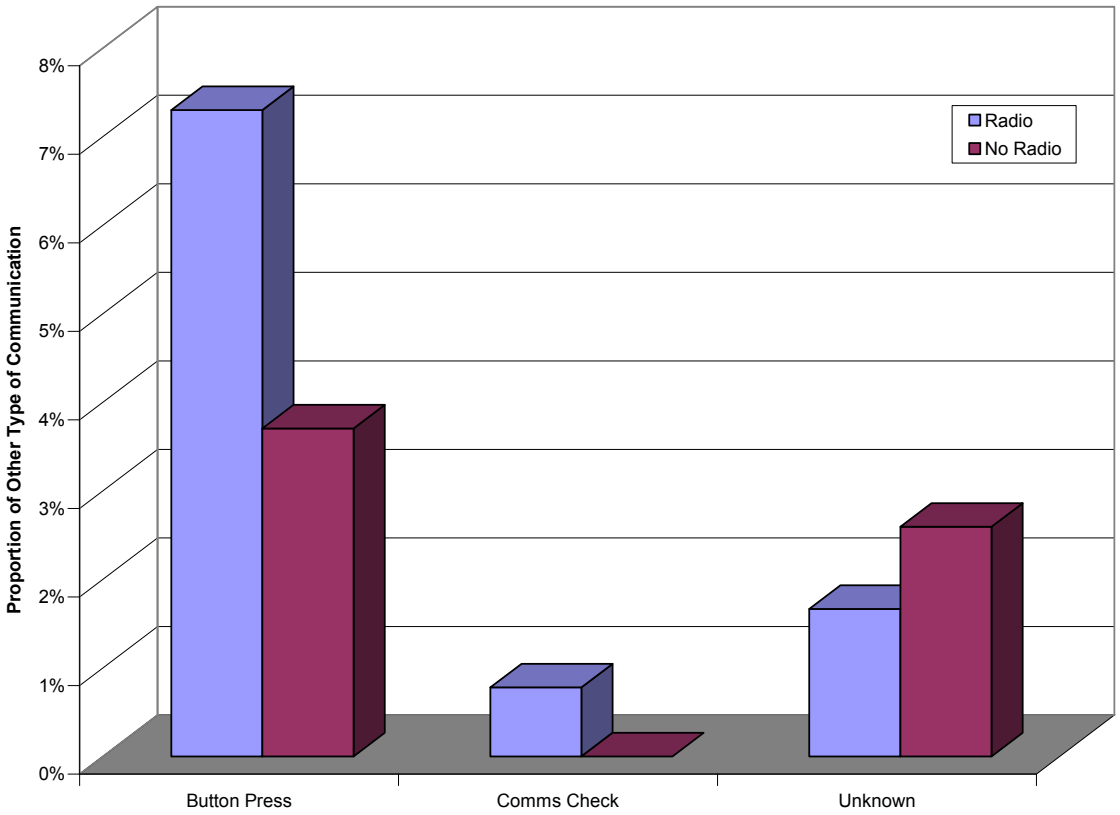
Exit Questionnaires

Participant Number	Assault Group	Likes	Dislikes	Improvements	Additional Comments
1	1.1	- easily used, clear voices - help provide comms with separated teams to know situation very good! - gives opportunity for information to be passed that might not have been	- can't talk if someone is in use, i.e. SC 2 ic can't talk if two members are talking, too many channels	- there should be a cutoff for SC/2 ic so that when they need to talk they can and not have to wait for others to finish; make it simple to use by having a toggle from section to team section - buttons were O.K.	- when in the game the rules for hand signals were too extreme; in real life you pan your area and catch the eye of another team and give more direct signals and also mouth what you wanted - it was hard to tell your team members details because of the proximity; in real life a person can be a few meters away and get signals and sound there is also more talking in real life even with silent movement - grenades are easier to throw in real life than it uses in the game; in real life you can drop a grenade around a corner or down stairs and not bounce it off walls
2	A	- liked the fact that I was able to cover my areas of fire and have my back turned from the team; while doing this I could whisper at 2ic and he could still hear me	- if I came under contract I couldn't be bothered to communicate with mates because that took to much effort – keyboard, comms…, keyboard, comms…etc(Danger)	- make comms systems voice activated, so while playing the game you won't have to move your fingers from the key pad (comms would be voice activated)	- overall I would have to say the comms were better in this game; however, if the game had more hand signal options that type of communication would have worked just as well. - In a real life situation hand signals would work just as well – the Section Commm or 2ic would point to you and give you area of fire with hand and eye gestures, also body language - Comms… worked well because HQ could say all that is neded without the confusion of hand signals - Hand signals just seemed to create frustration and could allow you to ask any questions
9	B	- you could hear what other people are saying - simple to use, basic	- once another member was on the comms, you have to wait until he is finished before you can say something	- make the voice comms system like a phone line!! - While holding the button you are connected to an open (public) line whereby 2 or more people can speak - Comms button should have been connected to the keyboard instead of having it's own unit; one must take their hand off the keyboard to use the comms	
5	A	- the ability to talk to my section at far distances or in different areas	- it is not an open channel like your phone, so if you have to say something important and someone else is on you can't send the message	- make an option for an open channel i.e. override for important information	- good idea if small, light and affordable

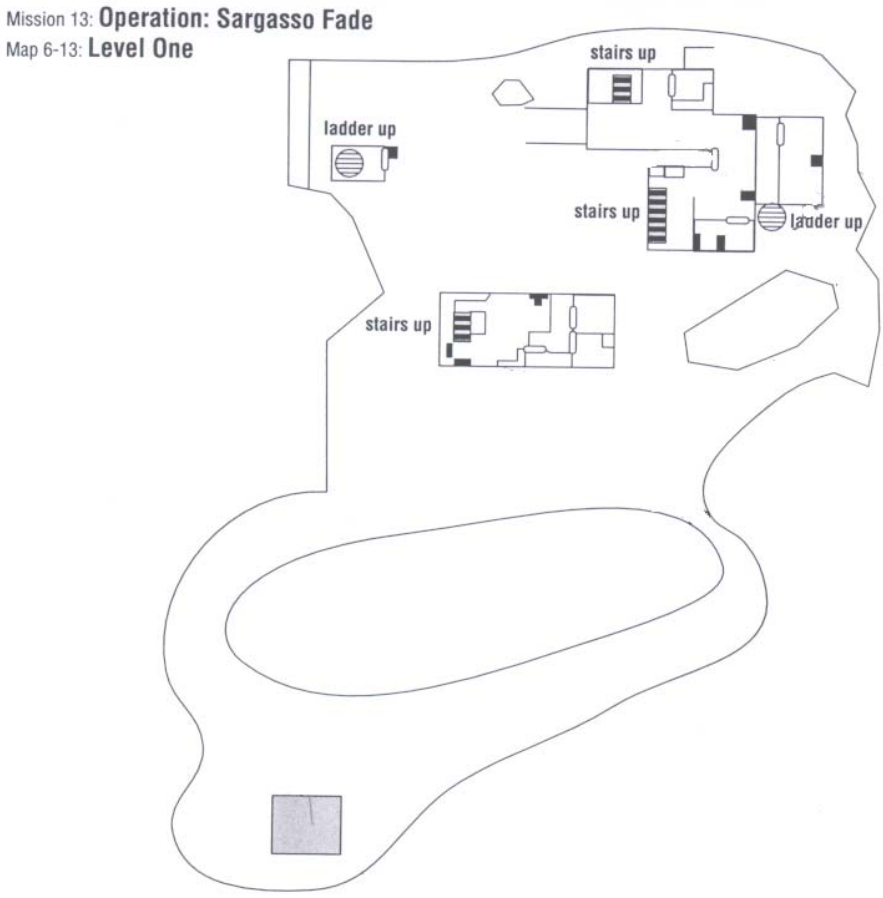
Participant Number	Assault Group	Likes	Dislikes	Improvements	Additional Comments
10	1	- direct contact with 2ic or ic - direct contact with Assault group and all of section	- if one channel is in use all other channels are blocked	- have different frequencies as that if on channel is in use all other channels are free for use by someone else, instead of being blocked by the use of that one specific channel	- more hand signals should be built into the game - have a jump button instead of the space bar - person should be able to go into the prone position for more safety and cover - better means for weapon accuracy should be thought of - longer range on grenade tossing i.e. vertical range
7	B	- loud and clear (voices) - headset with microphone	- 4 buttons (3 is best) - being cut off by section members when trying to communicate with 2ic or section command	- prioritize the nets in the order of section command-section 2ic, assault group and section nets in that order (e.g. that a section command-section 2ic net would override the section net	- being able to record all conversations throughout a mission (if such a system existed)
11	A	- clear reception - good microphone	- to large headset and mic piece to big - intercom box	- smaller headset, simple but steadfast mounting system for helmet - simple comms channel box	- comms box should not have cut off capability; in case messages are sent, team leaders should have all channels and not be cut off while talking to just one other member of the team - in the event of surprise situation, team members should be able to interrupt ongoing conversation to relay pertinent information - with this current system a third party cannot gain a conversation while two other team members are relaying information; you get a beep or closed channel – you cannot speak until current conversation or communication is terminated (point being…seconds count!)
8	B	- communication ease - knew where every one was knew what to do at all times; if I had a question, it could be answered	- distracted me from hearing surrounding sounds	- use on one ear only instead of both	- to be totally effective, it must be small, light and easy to use for field use
6	C	- all round (coms) i.e. individual (sec) you can hear your team leader clearly		- I don't think coms system should be touched – it works very well	

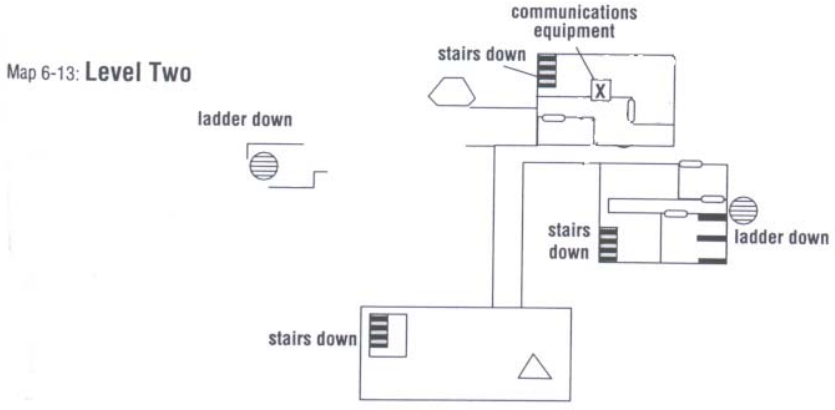
Participant Number	Assault Group	Likes	Dislikes	Improvements	Additional Comments
4	C	- the ability to communicate to all members - raise and lower volume - clarity	- too many buttons	- make headset smaller	-the option for section commander and 2ic to communicate on separate line, as well as the two groups -headset was adjustable; didn't interfere with anything (didn't have to move it around once in position)
3	B	- voice	-hand signals	- the microphone switch placed on the computer for a hands on effect – you're not fumbling while trying to talk to others	-didn't like the hand signals; it limited your communication; from the 3D to one dimension therefore you can't really talk back and forth effectively
12	C	- that I knew location of the other assault team, I was able to give information of my location to section c or 2ic without having to worry that he did not get the message teammate could also give my information of my location from another point of view	- sometimes you couldn't get your message though because someone else was on the line	- would put a line for each fire team	- in general the comms system was a great thing to have - definitely take a comm system out to the field; I believe that both teams work much better with the comm system

Frequency of “Other” Communications



Sample Mission Map





Annex B: Comms Examples

No Radio Mission 30 Transmission #113603SC – Example of complex transmissions

“No enemies dead…ah…no casualties….moving towards objective”

transfer of enemy status, own status, transfer own location

Task assignment – “Number 3, toss grenade in hallway”

Acknowledgement – “I read you there” (after an order)

Request – “Do you see where the blue team is?”

Transfer of status “I have a door that’s open and my sights are on it”, “I’m hit” “we have it secure” (referring to room)

Order of location “Alpha team, hold in this room”

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(U) SIREQ−TD (Soldier Information Requirements Technology Demonstrator) has determined that information transfer and communication between members in a dismounted infantry section is critical for mission success, and most soldier modernization programs have adopted an intra−section radio as part of their standard equipment. The purpose of this pilot study was to determine whether the addition of a radio would improve the communication and performance of an 8−soldier section in a computer−simulated 1st person shooter game. Specifically, we were interested in determining which aspects of communication and performance would or would not be enhanced, which radio network configurations were best, and whether there were differences in information exchanged with a radio and without.

Thirty−two (32) reserve force infantry soldiers participated in 27 virtual−reality multi−player missions, while seated at computer workstations in a laboratory over the course of 8 days, to evaluate the effects of adding a radio communications network to simulated dismounted infantry operations. In the No Radio condition, soldiers were required to whisper and use hand signals to communicate. In the Radio conditions, four networks were configured to control which section members could speak to each other. All communications were recorded and later content analyzed for type, function, references to friendlies vs. enemies, duration, pathways (role and network), and anticipation ratios. Outcome measures related to team performance (ammunition use, rounds taken and AG deaths) and team process (status awareness, teamwork, and workload) were also taken throughout the study. In addition, exit questionnaires and focus groups also explored participants' experience with and perceived benefits of radio communications.

Results indicated that although there was considerably more communication with a radio than without (i.e. a ratio of nearly 10 to 1), there was, in general, a very similar pattern of communication between conditions. For example, orders were the most common type of communication followed by information transfers both with a radio and without. However, there were twice as many orders (such as an order for location) in the No Radio condition compared to the Radio condition. The type of communication was somewhat more differentiated when soldiers had a radio. There were also similar patterns across conditions in the function of communication. In both conditions, the primary function of communication was related to location, followed by status. However, in the Radio condition, there were fewer communications related to location and more related to status compared to the No Radio condition. In both conditions, the Section Commanders (SC's) and second−in−command (2IC's) generated the most communication. Assault group members communicated twice as much when they had a radio compared to when they did not. In terms of network configuration, the most traffic was generated by the four−person assault group networks, followed by the leader net, and then the 8−person network. Although results from the mission performance data (rounds taken, fired and AG deaths) showed no difference between missions with a radio and without, perceived workload was significantly higher with a radio than without. This, however, might be a consequence of the sheer volume of radio activity and the undefined radio SOP.

Exit questionnaires and focus groups explored soldiers' perception of the radio communication system, and the relative advantages and disadvantages of having this kind of communication during infantry operations. In spite of the lack of quantitative data supporting improvements in performance from the presence of a radio, the focus group discussion at the end of the study indicated overwhelming support for the addition of a radio, and information transfer and coordination both within and between AG was rated as

more acceptable with a radio than without. Limitations and implications for future research 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.)

(U) Soldier Information Requirements Technology Demonstration Project; SIREQ TD; Radio Communication; Infantry Communication; intra−section communications; virtual reality games