DEFENCE **R&D** DÉFENSE

Speech Understanding in Noise in the Bison Command, Control, Communications and Intelligence (Bison C3I) Mobile Command Post (MCP)

Sharon M. Abel
Ann Nakashima
Ingrid Smith

Canada

Speech Understanding in Noise in the Bison Command, Control, Communications and Intelligence (Bison C3I) Mobile Command Post (MCP)

Sharon M. Abel
Ann Nakashima
Ingrid Smith

Defence R&D Canada – Toronto

Principal Author

Original signed by Sharon M. Abel

Sharon M. Abel

Defence Scientist, Individual Readiness Section

Approved by

Original signed by Stephen Boyne

Stephen Boyne

Section Head, Individual Readiness

Approved for release by

Original signed by K.C. Wulterkens

K. C. Wulterkens

For Chair, Knowledge and Information Management Committee

Abstract

This experiment compared subjects' ability to understand a series of messages presented either over a pair of loudspeakers or a headset used in the Bison Command, Control, Communications and Intelligence (Bison C3I) mobile command post (MCP). The messages were presented in quiet or in a background of noise heard in a light armoured vehicle driving along a highway, speech babble noise or both, at signal-to-noise ratios that were close to zero. The intention was to generate a baseline of results against which to judge divided auditory attention which entails the overlapping of messages from the various sources. Ten normal-hearing males were tested individually while seated in a mock up of the vehicle. The messages they heard were comprised of a Call Sign, Colour and Number combination. They were instructed to respond only to their assigned Call Sign which occurred with a 25% probability. While the percentage of hits exceeded 85% under all conditions, subjects performed significantly more poorly in the presence of the vehicle noise and when messages were presented over the loudspeaker. The results demonstrated that Signals Operators working in the Bison C3I MCP should have no difficulty with communication, as long as messages from various sources do not overlap and the speech and noise levels are similar.

Résumé

Dans la présente expérience, on a comparé la capacité des sujets à comprendre une série de messages présentés au moyen soit d'une paire de haut-parleurs, soit d'un casque d'écoute dans le poste de commandement mobile (MCP) de commandement, contrôle, communication et renseignement (C3I) du Bison. Les messages ont été présentés en mode silencieux ou en présence d'un bruit de fond qu'on entend dans un véhicule blindé léger en mouvement le long d'une autoroute, des bribes de conversation ou les deux, à des rapports signal/bruit presque nuls. Le but était de générer des données de référence des résultats par rapport auxquels il serait possible de déterminer l'attention auditive divisée qui permet le chevauchement de messages provenant de diverses sources. Dix hommes ayant une audition normale ont fait l'objet d'essais individuels, assis dans une maquette du véhicule. Les messages qu'ils entendaient comprenaient une combinaison d'indicatifs d'appel, de couleurs et de chiffres. Les sujets ont reçu l'instruction de répondre uniquement à l'indicatif d'appel qui leur avait été assigné, et qui avait 25 % de probabilité de se produire. Même si le pourcentage de probabilité dépassait 85 % dans toutes les conditions, les sujets ont réagi beaucoup moins bien en présence de bruit dans le véhicule et lorsque les messages étaient présentés au moyen des haut-parleurs. Les résultats ont démontré que les opérateurs des transmissions qui travaillent dans le MCP C3I du Bison ne devraient avoir aucune difficulté avec les communications, tant que les messages provenant de diverses sources ne se chevauchent pas et que le bruit et les conversations soient d'une intensité similaire.

This page intentionally left blank.

Executive summary

Speech Understanding in Noise in the Bison Command, Control, Communications and Intelligence (Bison C3I) Mobile Command Post (MCP)

Sharon M. Abel, Ann Nakashima and Ingrid Smith; DRDC Toronto TR 2010-169; Defence R&D Canada – Toronto.

Introduction: Signals Operators working in vehicular command posts listen to, transcribe and relay audio traffic generated by a number of audio sources (channels) in high-level noise. Typically, messages from these channels overlap in time. There are at least two types of noise, noise made by the vehicle while idling or driving along a highway and non-attended speech of the crew and passengers (speech babble). The experiment described herein was the first in a series of planned studies conducted in a mock up of the Bison Command, Control, Communications and Intelligence (Bison C3I) mobile command post (MCP). The ultimate goal of this research is the mitigation of auditory overload through new methods of displaying communiqués, as well as the implementation of technologies that integrate communications and noise attenuating hearing protection devices.

Method: In this baseline study, each of ten normal-hearing working-aged males was presented a list of 120 messages comprised of a Call Sign, Number and Colour combination, spoken by a male voice. Variations of the list were presented either over a pair of loudspeakers or the headset normally used on the Bison C3I MCP, in quiet or against a background of noise heard within a light armoured vehicle while driving along a highway, speech babble noise, or both, at speech-to-noise ratios that were close to zero. The subject was required to transcribe the messages using a computer keyboard only when they began with his assigned Call Sign (25% of the messages).

Results: Regardless of the listening condition, the percentage of hits exceeded 85%. False alarms were no greater than 4%. Analyses of variance applied to these two outcome measures indicated that the presence/absence of the vehicle noise, and the presentation channel, and their interaction were significant determinants of performance. Subjects performed more poorly when messages were presented over the loudspeakers in the vehicle noise. While relatively poorer scores were also evident when messages were presented in the babble noise, this factor failed to reach statistical significance.

Significance: The results of this baseline study have demonstrated that understanding and responding to messages from various channels on the Bison C3I MCP in backgrounds of either vehicle noise or speech noise should not be difficult. This conclusion is limited to the condition where the messages from the various channels do not overlap and the levels of the speech and noise are similar. It is expected that performance will deteriorate as task demands increase, e.g., the requirement to monitor and respond to overlapping messages from several channels, and as the speech-to-noise ratio decreases.

Future plans: Studies of divided auditory attention in noise are currently being planned. The benefit of visual cueing of message channels will be explored.

Sommaire

Speech Understanding in Noise in the Bison Command, Control, Communications and Intelligence (Bison C3I) Mobile Command Post (MCP)

Sharon M. Abel, Ann Nakashima and Ingrid Smith; DRDC Toronto TR 2010-169; Defence R&D Canada – Toronto.

Introduction : Les opérateurs des transmissions qui travaillent dans le poste de commandement des véhicules écoutent le trafic généré par un certain nombre de sources audio (canaux) en font une transcription et en assurent le relais, le tout en présence de bruit d'une intensité élevée. Normalement, les messages transmis dans ces canaux se chevauchent dans le temps. Il y a au moins deux types de bruit, à savoir le bruit produit par le véhicule au régime de ralenti ou en mouvement le long d'une autoroute et les conversations de l'équipage et des passagers non surveillés (bribes indistinctes de conversations). L'expérience décrite dans le présent document était la première d'une série d'études prévues menées dans une maquette du poste de commandement mobile (MCP) de commandement, contrôle, communication et renseignement (C3I) du Bison. L'objectif final de la présente recherche est l'atténuation de la surcharge auditive grâce à de nouvelles méthodes d'affichage des communiqués, ainsi que la mise en œuvre de technologies permettant d'intégrer les dispositifs de protection de l'ouïe qui atténuent les communications et le bruit.

Méthode : Dans cette étude de référence, on a présenté à chacun des dix hommes en âge de travailler et d'une audition normale une liste de 120 messages composés d'une combinaison d'indicatifs d'appel, de couleurs et de chiffres, énoncés par une voix masculine. Des variations de la liste ont été présentées au moyen soit d'une paire de haut-parleurs, soit d'un casque d'écoute normalement utilisés dans le MCP C3I du Bison, en mode silencieux ou avec un bruit de fond qu'on entend dans un véhicule blindé léger en mouvement le long d'une autoroute, des bribes de conversation ou les deux, à des rapports signal/bruit presque nuls. Le sujet devait transcrire les messages à l'aide du clavier d'un ordinateur uniquement lorsqu'ils commençaient, une fois donné l'indicatif d'appel qui lui était assigné (25 % des messages).

Résultats : Peu importe les conditions d'écoute, le pourcentage de probabilité dépassait 85 %. Les fausses alarmes ne dépassaient pas 4 %. Les analyses des variantes appliquées à ces deux mesures d'impact ont indiqué que la présence ou l'absence de bruit dans le véhicule et le canal de présentation, ainsi que l'interaction du bruit, constituaient d'importants déterminants de rendement. Les sujets ont réagi beaucoup moins bien lorsque les messages étaient présentés au moyen des haut-parleurs en présence de bruit dans le véhicule. Même si des notes relativement faibles ont été obtenues lorsque les messages étaient présentés en présence de bribes de conversations, ce facteur n'a pas réussi à acquérir une signification statistique.

Portée : Les résultats de la présente étude de référence ont démontré qu'il ne devrait pas être difficile de comprendre les messages provenant de divers canaux dans le MCP C3I du Bison, ou d'y répondre, en présence à l'arrière-plan soit du bruit du véhicule, soit des bribes de conversations. Cette conclusion est limitée à la condition que les messages provenant des divers canaux ne se chevauchent pas et que le bruit et les conversations soient d'une intensité similaire. On s'attend à ce que le rendement se détériore à mesure que les exigences des tâches augmentent, c'est-à-dire l'exigence de surveiller des messages provenant de plusieurs canaux qui se chevauchent et d'y répondre, et que le rapport parole/bruit diminue.

Recherches futures : Des études de l'attention auditive divisée en présence de bruit sont actuellement prévues. On étudiera l'utilité d'insérer des repères visuels dans les canaux de transmission des messages.

This page intentionally left blank.

Table of contents

List of figures

List of tables

Acknowledgements

This page intentionally left blank.

1   Introduction

1.1   Background

Signals Operators working in vehicular command posts listen to, transcribe, and relay audio traffic from multiple audio networks in high-level noise ambients. Messages from these networks overlap in time. There are at least two types of noise, noise made by the vehicle and non-attended speech of the crew and passengers (speech babble). The research described herein is the first in a series of studies conducted in a mock up of the Bison Command, Control, Communications and Intelligence (Bison C3I) mobile command post (MCP). The ultimate goal of this research is the solution of the problem of auditory overload by developing new methods of displaying communiqués intended for the operator and implementing newly available technologies that integrate communications devices and hearing protection. These strategies are designed to improve performance while mitigating the risks to hearing loss associated with long-term noise exposure. The results will transition to both aviation and naval environments.

Reports of studies examining operators' ability to process overlapping messages from multiple communications networks have appeared in the literature since the 1950's [1-3]. While listeners have no difficulty focusing attention on a single talker among many (the "cocktail party effect"), speech intelligibility suffers in competing message situations. Webster and Sharpe [4] cautioned that "stress and fatigue build up and confusion reigns, if an operator is deluged with multiple overlapping messages from which he has to make responsible decisions." They noted that characteristics that differentiate these messages, such as context, time of onset, apparent location, quality (pitch), or intensity, will aid understanding. As an example, Hawley et al. [5] studied speech intelligibility in the presence of one to three competing sources (the same male voice) positioned at relatively close, intermediate and far locations from the target source. Accuracy in key word identification decreased with an increase in number of competitors and increased with an increase in spatial separation. It was also found that outcome was affected by the way in which the messages are transcribed. Webster and Solomon [6] asked subjects to either write down 5-second messages in symbol form, transpose them alphabetically or tell a partner what to write down. More than twice as many errors occurred when responding to two instead of one message. The frequency of errors increased, if operators were required to transpose the message or repeat it to a co-worker, compared with writing it down.

Brungart [7] emphasized the importance of distinguishing between two types of background (masking) noise, energetic and informational. Energetic masking depends on the spectral overlap and thus the speech-to-noise ratio (SNR) of the speech and masker. In informational masking, the listener has to disentangle elements of the speech and masker that sound similar. Subjects in his study listened over headphones to target phrases in the presence of a single competing masker. The same information was presented to both ears. Three speech maskers were investigated, speech masker, continuous noise masker and speech-envelope modulated noise masker. The SNR was varied. Performance was more affected by informational than energetic masking. The greater the similarity of target and masker, the greater the decrement. Performance was best, if voice quality differed across talkers. In a subsequent study, Brungart et al. [8] demonstrated that variation in SNR in the range of 0 to -10 decibels (dB) had little differential effect on the intelligibility of the target talker. Recently, experiments have been conducted on the ability to understand several sources at the same time [9]. Voice quality and level differed across sources. As in selective attention, performance improved with spatial separation. Listeners actively attended to the harder-to-hear source and reported it first.

1.2 Purpose

This experiment was designed to assess the intelligibility of the messages presented over either the loudspeakers or the headset currently used in the Bison C3I MCP, in backgrounds of noise heard within a light armoured vehicle driving along a highway, speech babble noise, or both, at SNRs that were close to zero. The intention was to provide a baseline against which to measure decrements in auditory performance due to divided auditory attention, i.e., listening to and transcribing overlapping messages delivered by multiple sound sources, and the efficacy of strategies to combat auditory overload.

2 Method and Materials

2.1 Experimental Design

Ten normal-hearing, working-aged subjects were tested individually while seated at a workstation in a mock up of the Bison C3I MCP. Each subject was presented with eight listening conditions, consisting of combinations of the presence/absence of digitally recorded noise of a light armoured vehicle travelling along a highway, absence/presence of digitally recorded speech babble noise, and the audio output device (channel) over which speech materials were presented, either a pair of loudspeakers or diotic headset In diotic listening, the same stimuli are presented simultaneously to right and left ears. Subjects were given all eight conditions during a single session. The order of combinations of the two channels, and the absence/presence of the vehicle noise, were counterbalanced across subjects. In each of these four combinations, absence of speech babble preceded presence of speech babble.

In each of the eight listening conditions, subjects were presented a list of 120 messages. The messages were taken from the Coordinate Response Measure (CRM), a non standardized speech corpus for multi-talker communications research, adapted by Bolia et al. [10] to measure speech intelligibility in military environments. Each message in the corpus consists of a recording of a talker speaking a Call Sign followed by a Colour and Number, e.g., "Baron Blue Five". In all, there are 256 messages, made up of combinations of eight Call Signs (Charlie, Ringo, Laker, Hopper, Arrow, Tiger, Eagle and Baron), four Colours (Blue, Red, White and Green) and eight Numbers (1, 2, 3, 4, 5, 6, 7, and 8). The list of 256 possible messages spoken by each of four male and four female talkers were obtained from the Air Force Research Laboratory, Wright-Patterson Air Force Base, Dayton, Ohio. In the present study, only the list spoken by one of the males, randomly chosen, was used. Each of the 256 messages was sampled at 40 kHz and digitally stored as a single file on the hard drive of a computer. These formed a database from which to draw the subsets of messages that were presented in the experiment. These differed across subjects and conditions.

The eight Call Signs were randomly assigned to the first eight subjects, respectively. The remaining two subjects were tested with the two Call Signs that began with vowels (i.e., Arrow and Eagle), so that effect of vowel versus consonant onset on performance could be tested. The assigned target Call Sign was presented on 30 of the 120 trials (25% probability of occurrence). Across the 30 trials, presentation of each of the 32 Colour-Number pairings was random, with the restriction that each occurred only once. The remaining 224 Call Sign-Colour-Number pairings were randomly chosen for presentation on the remaining 90 trials, with the restriction that none occurred more than once. Each of the 120 messages was less than 3 seconds in duration. Successive phrases were separated by 2 seconds on average, resulting in a presentation rate of approximately 12 messages per minute. It took approximately 15 minutes to present the list of 120. Thus, the duration of the session, including breaks, was about 2.5 hours.

2.2 Subjects

Ten males (military and/or civilian) were recruited with the aid of a poster sent by email to employees of Defence Research and Development Canada – Toronto (DRDC Toronto) and the Canadian Forces Environmental Medicine Establishment (CFEME), and Canadian Forces (CF) personnel based at the Denison Armoury, Toronto, Canada. The study was restricted to males to

model the characteristics of personnel working in the Bison C3I MCP. Since subjects were to be tested in a sound proof room for an extended period of time with auditory materials, volunteers were screened by telephone for a history of head injury, claustrophobia, the use of medications that might affect the ability to complete the study and ear disease, including excess wax build up, hearing loss and tinnitus. They were also required to have good close up vision, since they would have to read instructions on a computer screen without the use of spectacles. The latter requirement ensured a good fit of the headset. As test materials would be spoken in North American English, subjects were required to speak fluent, unaccented, North American English, either as their first or second language. Those who passed these screening criteria underwent a hearing test conducted by a trained technician to ensure that pure-tone air conduction thresholds were no greater than 20 dB HL (decibels, hearing level) from 0.5 to 8 kHz. This represents no more than a slight hearing loss [11]. Only those with an interaural difference no greater than 15 dB at each of the four frequencies were admissible to the study. The latter constraint was designed to minimize a possible bias in listening to one or other ear. Those who were selected ranged in age from 21 to 52 years (mean 28.7 years). Hearing thresholds in the right and left ears at 500, 1000, 2000 and 4000 Hz were no greater than 10 dB HL.

2.3 Apparatus

A photograph of the Bison C3I MCP upon which the mock up was based is shown in Figure 1. The mock up was situated in the Noise Simulation Facility of DRDC Toronto. This facility is a semi-reverberant room, 10.55 m (L) by 6.10 m (W) by 3.05 m (H). An array of speakers comprising four low-frequency drivers (Bass Tech 7; ServoDrive Inc., Glenview, Illinois), eight mid-frequency drivers (Gane G218; Equity Sound Investments Inc., Bloomington, Indiana), and four high-frequency drivers (DMC 1152A; Electro-Voice, Burnsville, Minnesota) occupies the width of the shorter rear wall. These are powered by fourteen amplifiers (8 stereo model 4B and 6 mono model 7B; Bryston Ltd., Peterborough, Ontario). This array allows the acoustic simulation of a wide range of CF operational noise ambients, in terms of level, energy spectrum and time course, and is capable of producing noise levels in excess of 130 dB SPL (decibels, sound pressure level). The ambient noise of the facility is about 28 dB SPL [12].

The ambient noise level inside the Bison C3I MCP during highway driving of a light armoured vehicle has been measured to be 102 dBA (decibels, A-weighted) [13]. In the vehicle noise background condition for this study a digital recording of this ambient was played over the loudspeaker array in the test room (outside the mock up) at an at-ear level, beneath the headset, of 70 dBA. Digitally recorded speech babble noise [14] was played an at-ear level of 75 dB SPL over a powered monitor speaker (Model MS20S, Yamaha Canada Music Ltd., Toronto, ON). The speaker was located directly behind the subject's head at a distance of approximately 1 m. Speech materials were presented at an at-ear level of 75 dB SPL either over a headset (Racal Slimgard II RA108/1148; Esterline Technologies Corp, Bellevue, Washington) or a pair of tactical loudspeakers (G03A075-PFD; Accusonic Products, Bay Shore, NY). According to the manufacturers' specifications, the sound attenuation of the headset increases from 9 dB to 37 dB from 63 Hz to 4000 Hz. Active noise reduction (ANR) is optional and when implemented will increase the attenuation by 7 dB to 10 dB between 63 Hz and 500 Hz. ANR was not implemented in the present study. The loudspeakers were mounted on the framework of the mock up, facing directly ahead on either side of the head, at an approximately 40-degree angular distance of 1 m. Both the headset and loudspeakers are currently used by personnel operating the Bison C3I MCP. All of the at-ear levels comply with the Canada Labour Code statute [15] related to noise exposure in the workplace, and are considered safe for human hearing. The SNRs

chosen, +5 dB in the case of the vehicle noise, and 0 dB in the case of the speech babble have previously been shown to result in speech understanding in the range of 60% to 80% [16,17].

Subjects used a standard laptop keyboard for responding. The host computer controlled the timing of events, played the messages, recorded and displayed the trial by trial responses and computed the results for each condition in terms of hits (responding accurately when the subject's Call Sign was presented), misses (not responding to the Call Sign) and false alarms (responding to a Call Sign that had not been assigned).

Figure 1: The Bison C3I mobile command post.

2.4 Procedure

The study protocol was approved in advance by the Defence Research and Development Canada Human Research Ethics Committee. Each subject read the protocol and provided informed consent before participating. The terms and conditions of remuneration were discussed [18] and a date was scheduled for the study. All eight experimental conditions were presented in a single session. Prior to the first condition, each subject had the opportunity to listen to brief samples of the two noises and to listen and respond to a series of four messages played over each of the two channels. He was advised that he would be required to respond each time a message started with his assigned Call Sign. If the Call Sign was presented over the headset, he would respond by tapping four coded keys on a standard lap top computer keyboard, indicating the channel (Diotic), the Call Sign, the Colour and the Number, in order. If the Call Sign was presented over the loudspeakers, he would only be required to tap the space bar. Messages presented over the loudspeakers were intended to simulate information being relayed by the crew commander on the Bison C3I MCP. Normally, Signals Operators would not be required to transcribe and relay these. No feedback was given about the correctness of the responses. Short rests were given after each condition, with a longer break midway through the session.

This page intentionally left blank.

3   Results

The results of the study are shown in Table 1 and Figure 2. The table includes the mean percentage of hits (the number of correct responses to messages beginning with the subject's Call Sign divided by the number of trials on which that Call Sign was presented, i.e., 30), the mean hit range (the highest percentage of hits minus the lowest percentage of hits, and the mean percentage of false alarms, FAs (the number of times the subject responded to a Call Sign that was not his own divided by the number of trials on which one of the other Call Signs was presented, i.e., 90), for the 10 subjects. The hit range provides an index of the dispersion of scores across subjects. It is more sensitive to the presence of outliers than the conventional standard deviation [19], and thus provides information on the overall range of difficulty experienced for a given experimental condition. For presentations over the loudspeaker, subjects responded correctly (a hit) by pushing the space bar on the lap top. For presentations over the headset, subjects responded correctly (a hit) by pushing four keys corresponding to the Channel (Headset), Call Sign, Colour and Number presented. Subjects achieved their highest mean hits and lowest mean FAs in the absence of both the vehicle and babble noise, regardless of the channel over which the messages were played, and their lowest mean hits and highest mean FAs when both types of noise were present and messages were relayed over the loudspeaker.

A repeated measures analysis of variance (ANOVA) [19] was applied to the percentages of hits and FAs obtained for the ten subjects. For hits, statistically significant factors were the vehicle noise, the message channel, and the interaction of these factors ($p<0.002$, $p<0.006$, and $p<0.003$, respectively). In the absence of the vehicle noise, the difference due to the channel was less than 1%, averaged across absence/presence of the babble noise. In the presence of the vehicle noise, the percentage of hits for messages presented over the headset was 98.7% compared with 89.2% over the loudspeaker, averaged across absence/presence of the babble noise. This was in spite of the fact that the response required for messages presented over the headset was more complex. Although the presence of the babble noise did not affect the hit rate significantly, a relative reduction in the percentage of hits and relative increase in the hit range was apparent for the loudspeaker channel, without and with the vehicle noise. An ANOVA applied to the percentages of FAs showed a similar pattern. Significant factors were the vehicle noise ($p<0.04$) and message channel ($p<0.03$). The FA rate was 2.3% with the vehicle noise, compared with 0.2% without, averaged across the channel and absence/presence of the babble noise. FA rates for presentations over the loudspeaker and headset were 2% and 0.6%, respectively, averaged across absence/presence of the two noises.

Table 1: Mean percentages of hits (hit range) and FAs. (N=10)

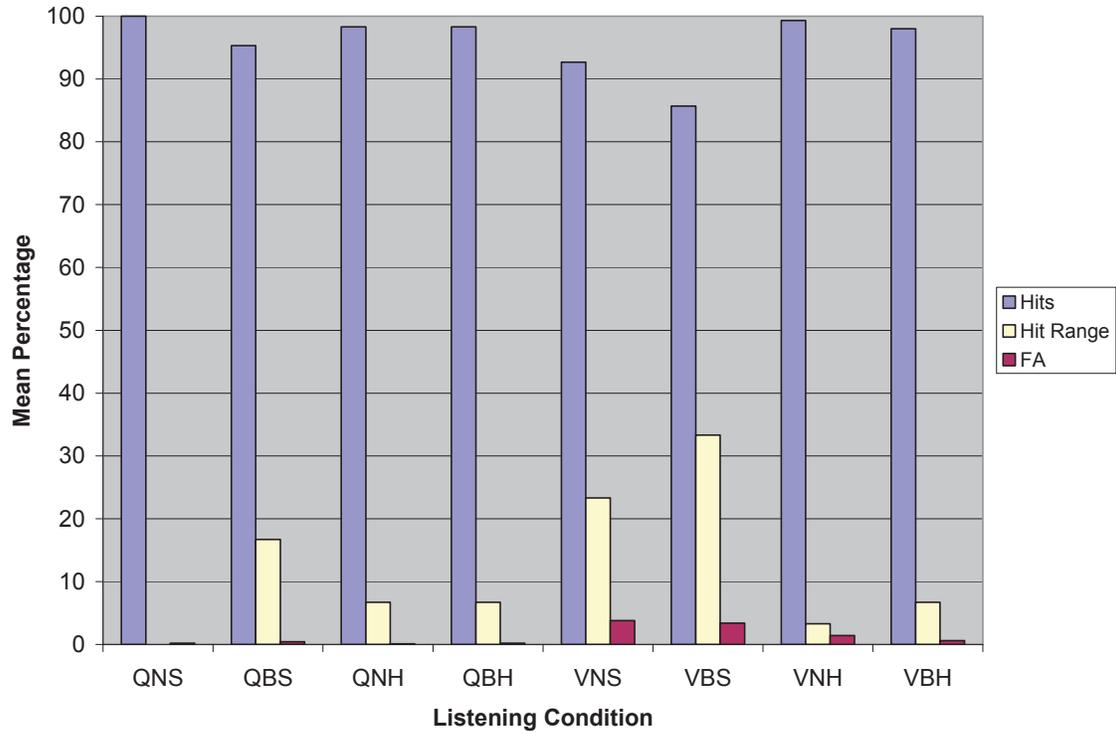| | | Message Channel | | | |
| | | Loudspeaker | | Headset | |
Vehicle Noise	Babble Noise	Hits	FA	Hits	FA
Absent	Absent	100.0 (0.0)	0.2	98.3 (6.7)	0.1
	Present	95.3 (16.7)	0.4	98.3 (6.7)	0.2
Present	Absent	92.7 (23.3)	3.8	99.3 (3.3)	1.4
	Present	85.7 (33.3)	3.4	98.0 (6.7)	0.6

Figure 2: Effect of vehicle noise(Q-absent, V-present), babble noise (N-absent, B-present), and message source (S-loudspeaker, H-headset) on hits, hit range and FAs.

In order to determine whether or not the significant outcomes observed may have been due to the characteristics of the Call Sign, hit and FA rates were compared for the six subjects who were assigned a Call Sign beginning with a consonant (Baron, Charlie, Hopper, Laker, Ringo, and Tiger) and the four subjects whose Call Sign began with a vowel (Arrow and Eagle). ANOVAs applied to the data indicated that for neither hits nor FAs was this characteristic of the Call Sign a significant main effect or significant in interaction with another factor. As in the analyses described above, the presence of the vehicle noise and the message channel significantly affected the outcome.

4 Discussion

This study was designed to assess subjects' ability to monitor and transcribe spoken messages delivered over the loudspeaker and headset currently used on the Bison C3I mobile command post. Messages were delivered from one or other of these two channels at a comfortable listening level. Messages from the two channels did not overlap, as they might during normal field conditions. The intention was to generate baseline data against which to judge the effect of divided attention, i.e., the requirement to monitor and transcribe overlapping messages delivered over several channels. The effects of energetic versus informational masking noise, generated by the vehicle driving along a highway and speech babble, respectively, were compared.

The results showed that the probability of a hit was relatively high for both message channels, ranging from 86% to 100% and FAs were relatively low, ranging from 0.1% to 3.8%. A decrease in hits was accompanied by an increase in the range of scores observed across subjects, signifying an increase in variability, as the task became more difficult. The decrement due to the noise created by a light armoured vehicle driving along a highway, although statistically significant, was only 4%, averaged across the two message channels and absence/presence of the babble noise. Based on previous reports in the literature [7], it was expected that informational masking from the babble noise would result in a greater deficit than energetic masking from the vehicle noise. Although performance was relatively poorer in the presence than in the absence of the babble noise, the difference was not statistically significant.

The message channel was a significant factor for outcome. Based on their performance, it was clear that subjects had more difficulty identifying their assigned Call Sign when it was presented over the loudspeaker compared with the headset. This may have been due to the poorer quality of the loudspeaker as a listening channel or the effect of the attenuation profile of the headset which is greatest at the speech frequencies. Although the message was audible, the noise floor, albeit low, may have served to degrade the clarity of the message. Another possible explanation is that, although the sound level of messages was the same at the ears, in the loudspeaker condition messages were external to the headset and thus were mixed perceptually with the vehicle and babble noises, while in the headset condition they were spatially separate.

The results of this baseline study have demonstrated that understanding and responding to messages from various sources on the Bison C3I MCP in backgrounds of either vehicle noise or speech noise should not be difficult. This conclusion is limited to the condition where the messages from the various sources are not overlapping and the levels of the speech and noise are similar. It is expected that performance will deteriorate as task demands increase, e.g., the requirement to monitor and respond to overlapping messages from several sound sources [3,9], and the SNR decreases [17].

This page intentionally left blank.

References

[1]   Cherry EC. Some experiments on the recognition of speech, with one and with two ears. J Acoust Soc Am 1953; 25(5):975-979.

[2]   Broadbent DE. The role of auditory localization in attention and memory span. J Exp Psychol 1954; 47:191-196.

[3]   Webster, JC, Thompson PO. Responding to both of two overlapping messages. J Acoust Soc Am 1954; 26(3):396-402.

[4]   Webster JC, Sharpe L. Improvements in message reception resulting from "sequencing" competing messages. J Acoust Soc Am 1955; 27(6):1194-1198.

[5]   Hawley ML, Litovsky RY, Colburn HS. Speech intelligibility and localization in a multi-source environment. J Acoust Soc Am 1999; 105(6):3426-3448.

[6]   Webster JC, Solomon, L.N. Effects of response complexity upon listening to competing messages. J Acoust Soc Am 1955; 27(6): 1199-1203.

[7]   Brungart DS. Informational and energetic masking effects in the perception of two simultaneous talkers. J Acoust Soc Am 2001; 109(3):1101-1109.

[8]   Brungart DS, Simpson BD, Ericson MA, Scott KR. Informational and energetic masking in the perception of multiple maskers. J Acoust Soc Am 2001; 1110(5), Pt 1: 2527-2538.

[9]   Ihlefeld A, Shinn-Cunningham B. Spatial release from energetic and informational masking in a divided speech identification task. J Acoust Soc Am 2008; 123(6): 4380-4392.

[10]   Bolia RS, Nelson WT, Ericson MA. A speech corpus for multitalker communications research. J Acoust Soc Am 2000; 107(2):1065-1066.

[11]   Yantis PA. Puretone air-conduction testing. In: Katz, J, editor. Handbook of clinical audiology. 3rd ed. Williams & Wilkins: Baltimore; 1985. pp. 153-69.

[12]   Nakashima A and Borland M. The noise simulation facility at DRDC Toronto. Technical Report, DRDC Toronto TR 2005-095, Defence R&D Canada – Toronto, October 2005.

[13]   Nakashima A, Borland M and Abel, SM. Measurement of noise and vibration in Canadian Forces armoured vehicles. Industrial Health 2007; 45:318-327.

[14]   Kalikow DN, Stevens KN, Elliott LL. Development of a test of speech intelligibility in noise using sentence materials with controlled word predictability. J Acoust Soc Am 1977; 61:1137-1351.

[15]   Department of Justice. Canada Occupational Health and Safety Regulations (SOR/86-304), Part VII, Levels of Sound. Ottawa, ON; 18 November 2009.

[16] Abel SM, Armstrong NM, Giguère C. Auditory perception with level-dependent hearing protectors. Scand Audiol 1993; 22:71-85.

[17] Abel SM, Krever EM. Auditory detection discrimination and speech processing in ageing, noise-sensitive and hearing-impaired listeners. Scand Audiol 1990; 19:43-54.

[18] Duncan M, Eaton D, Hendriks T, Keefe A, McLellan TM, Michas RD, Thompson MM. DRDC Toronto guidelines for compensations of subjects participating in research studies. Technical Memorandum, DRDC Toronto TM 2008-138, Defence R&D Canada – Toronto, September, 2008.

[19] Daniel WW. Biostatistics: A foundation for analysis in the health sciences. 3rd ed. Wiley: New York; 1983.

List of symbols/abbreviations/acronyms/initialisms

ambient	background
ANOVA	analysis of variance
ANR	active noise reduction
C3I	Command, Control, Communications and Intelligence
CF	Canadian Forces
CFEME	Canadian Forces Environmental Medicine Establishment
CRM	Coordinate Response Measure
dBA	decibels, A-weighted; a measure of sound level, weighted to model the frequency response characteristics of the human ear
dB HL	decibels, hearing level; a measure of sound level, relative to normal hearing threshold
dB SPL	decibels, sound pressure level, relative to 0.0002 μbar
diotic	The same stimulus is presented to both ears simultaneously.
DLCSPM	Directorate of Land Command Systems Program Management
DRDC Toronto	Defence Research and Development Canada - Toronto
FA	false alarm
HEEC	Human Effectiveness Experimentation Centre
kHz	kilohertz, thousand cycles per second; a measure of stimulus frequency
MCP	mobile command post
SNR	speech- to-noise ratio

Defence R&D Canada

Canada's Leader in Defence
and National Security
Science and Technology

R & D pour la défense Canada

Chef de file au Canada en matière
de science et de technologie pour
la défense et la sécurité nationale

DEFENCE **R&D** DÉFENSE