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Effects of Integrated Hearing Protection Headsets on the Quality of Radio Communications

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Abstract

The speech intelligibility of a personal role radio (PRR) with integrated hearing protection headsets (IHPH) was investigated. The standard PRR communication headset is comprised of a one-sided earcup and a boom microphone, and does not provide hearing protection. IHPH devices provide simultaneous hearing protection, communication and enhanced hearing capability. Two different tests of speech intelligibility were used (modified rhyme test [MRT] and speech perception in noise [SPIN]) to evaluate the quality of radioed speech over the standard PRR headset (SH), the Nacre QuietPro® (QP) and the Silynx QuietOps™ (QO). The highest scores on the MRT and SPIN tests in background noise were obtained using the SH, followed by the QP and the QO. However, the QP was given a higher total user acceptance rating score than the SH. Both the QP and SH were rated relatively higher than the QO. Given that hearing protection will be required in most operational environments, the QP provided the best combination of speech quality, hearing protection and usability.

Résumé

L'intelligibilité de la parole en provenance d'un poste radio personnel (PRR) muni de casques d'écoute avec dispositif intégré de protection de l'ouïe (DIPO) a fait l'objet d'une évaluation. Le casque d'écoute réglementaire avec microphone dont est équipé le PRR se compose d'une seule coupelle à oreille et d'un microphone monté sur tige et n'offre aucune protection de l'ouïe. Les DIPO offrent à la fois protection de l'ouïe, capacité de communication et capacité auditive accrue. Deux tests différents d'intelligibilité de la parole (le test MRT anglais de rimes modifiées et le test SPIN anglais de perception de la parole en présénce de bruit) ont servi à évaluer la qualité de la sortie de parole sur le casque d'écoute réglementaire du PRR (casque réglementaire), le casque Nacre QuietPro® (QP) et le casque Silynx QuietOps™ (QO). Dans le cas du MRT et du SPIN administrés avec bruit de fond, le casque réglementaire a affiché les meilleurs résultats, suivi du casque QP et ensuite du casque QO. Le casque QP a obtenu un meilleur résultat total que le casque réglementaire en ce qui concerne l'acceptation par l'utilisateur. Le casque QP et le casque réglementaire ont obtenu tous les deux un résultat relativement supérieur à celui du casque QO. Étant donné que la plupart des environnements opérationnels exigeront un dispositif de protection de l'ouïe, le casque QP offre la meilleure option combinant qualité de la parole, protection de l'ouïe et facilité d'emploi.

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Executive summary

Effects of Integrated Hearing Protection Headsets on the Quality of Radio Communications:

Ann Nakashima; Sharon M. Abel; DRDC Toronto TR 2009-074; Defence R&D Canada – Toronto; July 2009.

Background: Communication between soldiers on the ground is often hindered by various types of noise. The noise can be continuous (e.g., vehicle noise) or impulsive (e.g., gunfire and blasts). Conventional radio headsets do not provide hearing protection, and conventional hearing protection devices have a negative impact on communication and the ability to localize sounds, decreasing situational awareness. It is of interest to consider integrated solutions to find the best combination of hearing protection, communication capability and usability in the field. In this study, speech intelligibility was tested using the personal role radio (PRR), which is standard issue for Canadian Forces (CF) dismounted soldiers. The PRR was used with a standard headset (SH; one-sided earcup, no hearing protection) and two integrated hearing protection devices: the Nacre QuietPro® (QP) and the Silynx QuietOps™ (QO). A secondary objective was to obtain user acceptance ratings by means of a questionnaire.

Method: Five male subjects with normal hearing thresholds and who were fluent in English participated in the study. Subjects performed two tests of speech intelligibility in 75 dBA background noise: the Modified Rhyme test (MRT) and the Speech Perception in Noise test (SPIN). The tests were conducted using one subject as the talker and a second subject as the listener. During each experimental session, the subject pair alternated roles as talker and listener, and completed the MRT and SPIN tests using each of the three headsets. A questionnaire probing headset user acceptance was administered after each headset was used. Subjects were paired such that all possible subject combinations were used; therefore, each subject participated in four sessions for a total of 10 experimental sessions.

Results: For the MRT, subjects performed the best using the standard PRR headset (SH, 89%), followed by the QP (83%) and then the QO (70%). Performance using the SPIN followed a similar trend: 93% for the SH, 87% for the QP and 70% for the QO. Performance on both of the tests was significantly better using the SH than both the QP and QO. Mean user acceptance scores were highest for the QP (48.8), followed closely by the SH (47.6). Both were rated relatively higher than the QO (35.9).

Significance: Given that military personnel will be required to wear hearing protection in most operational environments, of the three headsets tested the QP provided the best combination of speech quality, hearing protection and user acceptance.

Future plans: It may be of interest to consider speech intelligibility and user acceptance of the SH in combination with earplugs that offer protection from impulse noise and talk-through capability. This would provide an alternative, lower-cost solution for integrated hearing protection and communication in the field.

Sommaire

Effects of Integrated Hearing Protection Headsets on the Quality of Radio Communications:

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Contexte: Divers types de bruit viennent souvent altérer la communication entre les soldats sur le terrain. Il peut s'agir d'un bruit continu (p. ex., le bruit d'un véhicule) ou impulsionnel (p. ex., un tir de canon ou une explosion). Les casques d'écoute traditionnels n'offrent aucune protection de l'ouïe alors que les dispositifs traditionnels de protection de l'ouïe nuisent à la communication et à la capacité de localiser la source du bruit, ce qui limite la connaissance de la situation. Il convient donc d'examiner des solutions mixtes afin de trouver le casque qui offre la meilleure combinaison de protection de l'ouïe, de capacité de communication et de facilité d'emploi sur le terrain. Dans l'étude, l'évaluation de l'intelligibilité de la parole a été effectuée à partir du poste radio personnel (PRR), lequel constitue un article réglementaire pour les soldats débarqués des Forces canadiennes. Le PRR a été évalué avec un casque d'écoute réglementaire (une seule coupelle à oreille et aucune protection de l'ouïe) et avec deux dispositifs intégrés de protection de l'ouïe : le Nacre QuietPro® (QP) et le Silynx QuietOpsTM (QO). Parallèlement, on a évalué le degré d'acceptation de l'utilisateur à l'aide d'un questionnaire.

Méthode: Cinq hommes ayant un seuil d'audition normal et parlant couramment anglais ont pris part à l'étude. Les sujets ont effectué les deux tests d'intelligibilité de la parole (le test MRT anglais des rimes modifiées et le test de SPIN anglais perception de la parole en présence de bruit) avec un bruit de fond de 75 dBA. Pour chaque test, un sujet remplissait le rôle de celui qui parle et un autre sujet, le rôle de celui qui écoute. Ils inversaient ensuite les rôles et répétaient l'expérience avec chacun des trois casques d'écoute. Après l'utilisation de chaque casque d'écoute, le sujet remplissait un formulaire sur l'acceptation de l'utilisateur. Les sujets ont été jumelés de telle sorte que toutes les combinaisons possibles soient réalisées. Ainsi, chaque sujet a participé à quatre séances, pour un total de dix séances expérimentales.

Résultats: Dans le cas du MRT, les sujets ont affiché les meilleurs résultats avec le casque réglementaire du PRR (89 %), suivaient ensuite les résultats pour le QP (83 %) et ceux pour le QO (70 %). Les résultats présentaient la même tendance dans le cas du SPIN : à savoir, 93 % (casque réglementaire); 87 % (QP) et 70 % (QO). Dans le cas des deux tests, le casque réglementaire a donné de bien meilleurs résultats que les casques QP et QO. En moyenne, le taux d'acceptation de l'utilisateur était supérieur dans le cas du casque QP (48,8 %), suivi de près par celui du casque réglementaire (47,6 %). Ces deux casques ont obtenu une cote relativement supérieure à celle du casque QO (35,9 %).

Importance: Étant donné que le personnel militaire devra porter un dispositif de protection de l'ouïe dans la plupart des environnements opérationnels, le casque QP est celui qui, des trois casques d'écoute évalués, constitue la meilleure option combinant protection de l'ouïe, capacité de communication et facilité d'emploi.

Perspectives: Il conviendrait peut-être d'évaluer l'intelligibilité de la parole et l'acceptation de l'utilisateur dans le cas du casque réglementaire utilisé avec bouchons d'oreille, lesquels protègent contre le bruit impulsionnel tout en permettant la communication. Cette formule

offrirait une solution de rechange économique qui permettrait d'assurer la protection de l'ouïe et la communication sur le terrain.

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1   Introduction

The effects of conventional hearing protection devices on speech intelligibility have been studied for many decades (e.g. Kryter, 1946; Abel et al, 1982). Military operational environments are highly dynamic, containing high noise levels with a broad range of frequencies and temporal characteristics. Military personnel require equipment that will not only protect them from high noise exposure, but also allow them to communicate with other crew or platoon members. Over the years, new technologies have been developed to address these demands. For example, the incorporation of active noise reduction (ANR) technology in earmuffs has led to both improved communications and hearing protection in aircraft (Gower and Casali, 1994; McKinley et al., 1996).

To date, much of the work on the intelligibility of radio communications has focused on aircraft (e.g. Ribera et al, 2004). Communication between soldiers on the ground, whether mounted or dismounted, is also of critical importance. Soldiers on the ground may be exposed to various types of noise, from continuous noise inside an armoured personnel carrier to high intensity impulse noise from gunfire and blasts. Conventional radio headsets do not provide hearing protection, while conventional hearing protection devices (HPDs) have a negative impact on communication and the ability to localize sounds, which decreases situational awareness. This is particularly true for individuals with pre-existing hearing loss (Abel et al., 1993). To address these problems, integrated hearing protection headsets (IHPH) have been developed. IHPH systems combine communication capability with hearing protection. The insert earplugs contain transducers which serve several purposes: 1) to feed the incoming communication channel through to the ear, 2) to transmit the outgoing communication from the user (may be a microphone that is integrated into the earplug or an external boom microphone), 3) to capture ambient sounds and feed them through to the ear and 4) to provide ANR. It has been shown that IHPH systems allow for improved sound localization capability over conventional headsets (Abel et al., 2007).

In order to maintain situational awareness, dismounted soldiers must have both protection from high noise levels and the ability to communicate effectively by radio. It has already been determined that IHPH devices can provide adequate hearing protection and sound localization capability. In this study, the quality of speech communication that is afforded by these devices was investigated. A secondary objective was to obtain user acceptance ratings by means of a questionnaire. The study was designed to conform to the American National Standard for measuring the intelligibility of speech over communication systems (ANSI S3.2-1989 (R1999)).

2 Method

2.1 Subjects

ANSI S3.2-1989 (R1999) lists the following criteria for selection of subjects (ANSI, 1999):

- At least five talkers and at least five listeners shall be used;
- The number of talkers shall be equal to or greater than the number of listeners;
- The sample of talkers and listeners shall be representative of the expected user population;
- Subjects shall have hearing thresholds that are no higher than +20 dB HL and no lower than -10 dB HL at frequencies between 125 and 8000 Hz.

Five male subjects (age range 22-39 years) who were fluent in English participated in this study. All subjects were screened for a history of ear disease and hearing thresholds greater than 20 dB HL bilaterally between 0.25 kHz and 8 kHz. Accurate results were not obtained for 0.125 kHz due to equipment limitations. Subjects were asked to avoid loud noise or music exposure for 24 hours before each experimental session.

Protocol approval was obtained from the Human Research Ethics Committee (HREC) of Defence Research and Development Canada (DRDC). Participants were recruited from within DRDC Toronto and the Land Force Central Area (LFCA) at the Denison Armoury in Toronto. Subjects gave their written consent prior to participating in the experiment and were remunerated for their participation according to guidelines established by DRDC Toronto.

2.2 Apparatus

The experiment was conducted in the Noise Simulation Facility at Defence Research and Development Canada – Toronto (DRDC Toronto)   The facility is a semi-reverberant room (11 x 6 x 3 m^3) with an ambient of about 28 dB SPL. The background noise (75 dBA pink noise) was presented from an array of 8 sub-low (Gane G218), 2 low (ServoDrive Bass Tech 7), 4 mid- (ElectroVoice) and 4 high-frequency (ElectroVoice) loudspeakers, powered by twelve Bryson amplifiers (stereo model 4B and mono model 7B). For details see Nakashima and Borland, 2005. The array spanned the shorter wall of the room, facing the subjects at a distance of 4.7 m . The subjects were seated 2.2 m apart, separated by a barrier (Figure 1). The subject positions were chosen such that the background noise spectra were matched. The noise spectra at the two positions are shown in Figure 2.

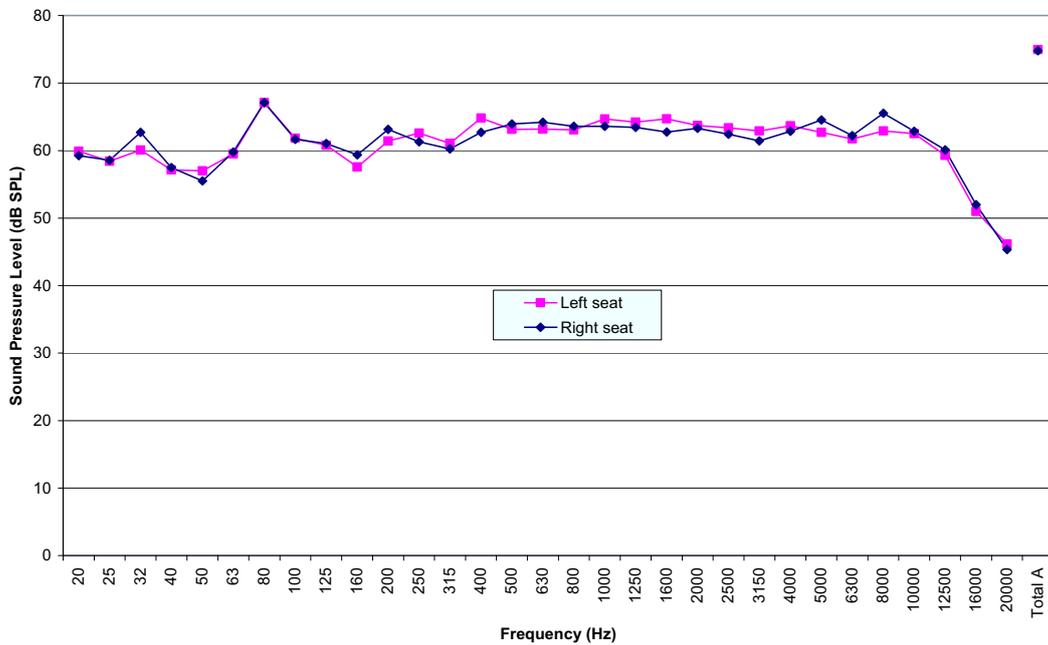*Figure 1: Experimental setup in the Noise Simulation Facility.*

Figure 2: Background noise spectra (pink noise, total 75 dBA) at the two subject positions.

The subjects communicated using Personal Role Radios (PRR; Marconi_Selenia Communications), which are standard issue in the Canadian Forces (CF) for dismounted soldiers. Three different headsets were used in combination with the PRR: the standard PRR headset (SH),

a Nacre QuietPro® headset (QP) and a Silynx QuietOps™ headset (QO) (see Figure 3). The SH consists of a one-sided earcup for listening and a boom microphone for talking. The QP and QO offer hearing protection, radio communication and enhanced hearing capabilities. The QP and QO are similar in functionality, but have some design differences that may affect their usability and quality of voice communications. They have insert earplugs (canal tips) that provide passive hearing protection and electronics that allow for ANR when the ambient noise level exceeds 85 dBA. Microphones are built into the canal tips which capture the speech of the user, as well as ambient sounds. Two volume controls are available: one for the radio communications and one for the ambient sounds. Control of the ambient sound level allows users to decrease the surrounding noise levels, or increase desirable sounds (e.g., somebody talking from a distance). Three different sizes of canal tips were available for the QP and five different sizes for the QO. Both systems had a self-check feature that informs the user if the canal tips are inserted properly and are providing an adequate seal.
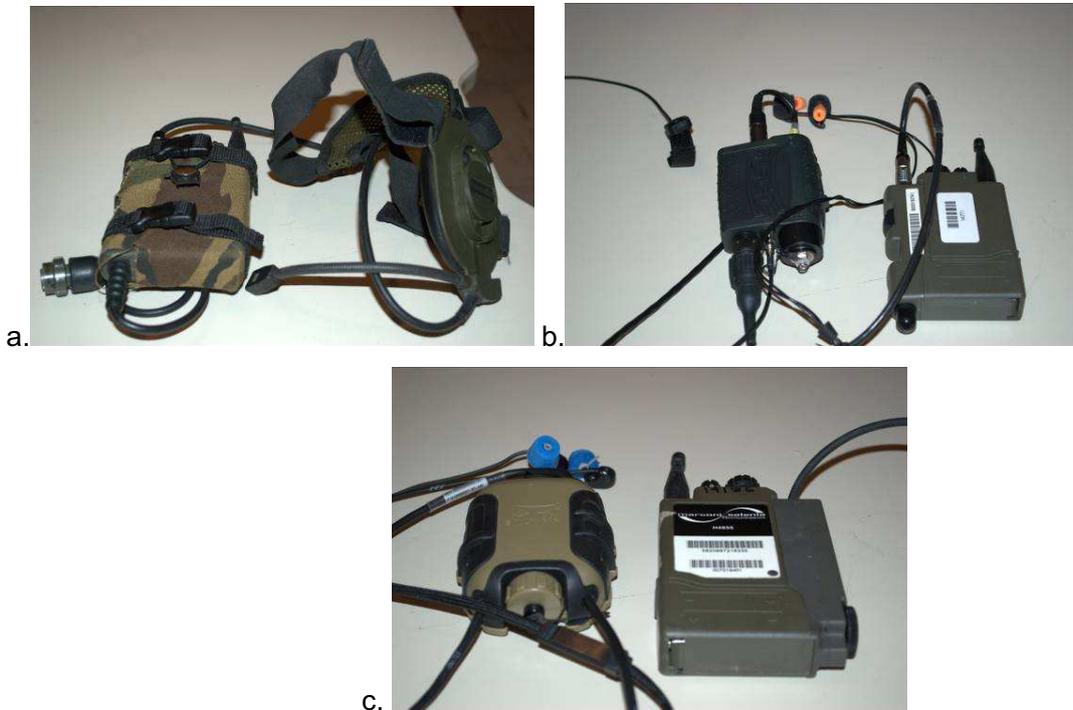

a.

b.

c.

Figure 2: Personal role radio (PRR) with a) Standard headset (SH), b) Nacre QuietPro® (QP), c) Silynx QuietOps™ (QO).

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2.3   Speech Materials

Two tests of speech understanding were used. The Modified Rhyme Test (MRT) is a test of consonant discrimination (Bell et al., 1972), recommended by ANSI S3.2-1989 (R1999). A sample of the MRT is shown in Annex A. The listener was provided with a typewritten list of 50 sets of six monosyllabic words in the form of consonant-vowel-consonant (CVC). Half of the sets contrast the initial consonant (e.g., "raw, paw, law, jaw, thaw, saw") and the other half contrast the final consonant (e.g., "teach, tear, tease, teal, team, teak"). The talker read one word from each set embedded in a carrier phrase ("The word is _____ ") and the listener circled the word heard out of the six possible choices. In total, 14 different combinations of MRT word lists were used (four word lists with 4-6 combinations of target words each). The word lists were counterbalanced across subject pairs.

The Speech Perception in Noise test (SPIN) assesses word recognition (Kalikow, Stevens and Elliott, 1977). A sample of the SPIN test is shown in Annex B. Fifty sentences were presented in sequence by the talker and the listener was required to write down the final word in each. In half of the sentences, distributed randomly throughout the list, the final word was highly predictable from the context. In the remainder, there were no contextual cues. Eight different sets of 50 sentences were used, counterbalanced across subject pairs. For the MRT and SPIN, guessing was encouraged and no feedback was given about the correctness of the responses.

2.4   Questionnaire

The subjects filled out a questionnaire for each headset, for each experimental session. The questionnaire probed the usability and effectiveness of the three headsets for communication. The questionnaire is shown in Annex C. Subjects were asked to provide a rating score for each question and to provide written comments.

2.5   Experimental Protocol

Subjects attended a training session prior to the commencement of the experimental sessions. They were instructed on how to insert the QO and QP canal tips in their ears and to check for a proper fit. By going through this process, the correct size of canal tips for each subject was determined. The canal tips for each subject were stored in separate envelopes with their subject ID and they were re-used for the experimental sessions until replacement was required (e.g., a proper fit could no longer be obtained). The subjects were then briefed on how to use the PRRs and headsets, and practiced communicating with at least one other subject in quiet and with the background noise on. Once the subjects had been familiarized with the radios and headsets, they were shown sample MRT and SPIN lists and instructed on how they should be read in terms of pronunciation and speech rate. Subjects were then given the opportunity to practice reading the word lists with at least one other subject, with the background noise turned on.

Once the training was completed, the five subjects were paired such that all possible combinations were tested. Thus, each subject participated in four experimental sessions, and a total of 10 sessions were conducted. Each experimental session for a given subject were separated by a period of one week to minimize possible carry over of learning effects.

During the experimental sessions, the QO was set to one level below the default volume, and the QP was set to the default volume. These volumes levels have anecdotally been perceived as being zero gain, or close to a natural level when listening to ambient sounds. The PRR volume level was set to maximum. The experimenter remained in the control room and listened over the radio network to monitor speech rate, broken communication and equipment malfunctions. The

subjects were also monitored with a video camera. The talker was only allowed to repeat if the sentence was read incorrectly or the entire sentence was missed (e.g., due to the talker not pressing the push-to-talk button). No repeats were allowed for reasons related to the PRR or headset (e.g., excessive noise or dropouts in the communication channel), except in the case of battery failure.

The subjects fitted themselves with the headset and were seated as shown in Figure 1. With the background noise turned on (75 dBA pink noise), the talker read through one MRT list and one SPIN list while the listener recorded their responses on paper. The subjects then switched roles and repeated the procedure. Upon completion, the experimenter turned off the noise and administered the questionnaire for that headset. The subjects were then fitted with the next headset, and the procedure was repeated until all three headsets had been used. The order of the headsets was counterbalanced across subject pairs.

2.6   Data Analysis

This study is a within-subject repeated measures design. Each of the five subjects participated in four sessions such that all possible subject pairs were used. The MRT and SPIN scores for each subject (listeners) were averaged across the four sessions (talkers). Repeated measures analyses of variance (ANOVA; Daniel, 1983) were performed on the averaged SPIN and MRT scores using SPSS Statistics 17.0 (Statistical package for social sciences, SPSS Inc., 2008). Statistical significance was set at $p < 0.05$. For the MRT data, the dependent variables were headset type (SH, QO and QP) and position of contrasting consonant (initial and final). For the SPIN data, the dependent variables were headset type and context (none or high). Post-hoc pairwise comparisons for headset were computed using Fisher's least significant difference (LSD).

Subjective user acceptance scores for each headset were calculated based on the questionnaire responses (Annex C). Each subject completed the questionnaire four times for each headset (once per session), so each headset was rated a total of 20 times. The score for each question ranged from 1 (completely unacceptable) to 7 (completely acceptable). The average scores for each question were added to give a total user acceptance score for each headset. Because the questionnaire and rating scale were not validated measures, they were not subjected to statistical analysis.

3   Results

Repeated measures ANOVA indicated that there were no significant differences between hearing thresholds for the left and right ears within subjects. The mean hearing thresholds were 7.9, -0.9, -0.6, -1.8, 2.0 and -0.2 dBHL for 250, 500, 1000, 4000 and 8000 Hz, respectively with standard deviations ranging from 4 to 8 dB.

The results for the MRT are shown in Table 1. A repeated measures ANOVA applied to these data showed a main effect of headset ($p < 0.00004$) but no main effect of consonant position. The highest accuracy (percentage correct) was obtained with the SH, followed by QP and QO. Post-hoc pairwise comparisons using Fisher's least significant difference revealed significant differences between all pairs of the headsets (SH and QO, $p < 0.001$; SH and QP, $p < 0.035$; QO and QP, $p < 0.003$).

Table 1: MRT results (percentage correct and standard deviation) for the three headsets.

	Standard Headset (SH)	Silynx Quiet Ops™ (QO)	Nacre Quiet Pro® (QP)
Initial consonant	89.9 ± 2.5	69.7 ± 5.0	81.8 ± 3.3
Final consonant	88.3 ± 4.1	70.1 ± 5.6	84.6 ± 5.1

The results for the SPIN test are shown in Table 2. A repeated measures ANOVA applied to these data showed a main effect of headset ($p < 0.001$) and contextual cues ($p < 0.001$) and their interaction was significant ($p < 0.001$). Similar to the MRT, the most accurate result in terms of percentage correct was obtained with the SH, followed by the QP and QO. Post-hoc pairwise comparisons using Fisher's LSD revealed significant differences between all pairs of headsets (SH and QO, $p < 0.007$; SH and QP, $p < 0.035$; QO and QP, $p < 0.017$).

Table 2: SPIN results (percentage correct and standard deviation) for the three headsets.

	Standard Headset (SH)	Silynx Quiet Ops™ (QO)	Nacre Quiet Pro® (QP)
High contextual cues	99.6 ± 0.5	87.0 ± 9.8	96.9 ± 2.7
No contextual cues	86.8 ± 4.1	52.4 ± 12.4	77.6 ± 10.6

For the questionnaire data, the average scores for each question were added to give a total user acceptance score for each headset. The results are listed in Table 3. The highest total score was given to the QP (48.8), followed closely by the SH (47.6). The QO was rated relatively lower than the other two headsets (35.9).

Table 3: Subjective user acceptance scores (and standard deviation).

	Standard Headset (SH)	Silynx Quiet Ops™ (QO)	Nacre Quiet Pro® (QP)
Overall ease of use	6.3 ± 1.1	5.1 ± 1.1	6.1 ± 0.6
PTT (push-to-talk) button ease of use	6.0 ± 1.2	4.6 ± 1.4	6.4 ± 0.8
Earphone/Headset comfort	6.1 ± 1.1	4.4 ± 1.7	5.8 ± 1.0
Speech fidelity (speech distortion)	6.1 ± 1.1	4.1 ± 1.6	5.6 ± 1.2
Clarity of communication (noise in the channel)	5.9 ± 1.3	4.5 ± 2.1	6.3 ± 1.0
Continuity of communication	6.1 ± 1.1	5.0 ± 1.7	6.2 ± 0.7
Annoyance due to ambient noise (1 = highly annoying, 7 = not annoying)	5.3 ± 1.4	4.4 ± 1.7	6.3 ± 1.0
Overall rating	6.0 ± 1.1	4.0 ± 1.8	6.3 ± 1.0
TOTAL SCORE	**47.6 ± 9.4**	**35.9 ± 13.0**	**48.8 ± 7.3**

The questionnaire comments indicated that the SH was easy to use, comfortable to wear, and generally provided clear communication. There were a few comments about the movement of the boom microphone, which may have caused broken speech transmission. For the QO, users commented that the speech was muffled or unclear, the PTT button was difficult to use (resulting in broken communication) and the canal tips were uncomfortable for long-term wear. User comments on the QP indicated that the canal tips were difficult to fit, but acceptably comfortable once they were inserted properly. There were mixed comments on the speech clarity and noisiness of the channel. Overall, the comments indicated that the SH was preferred, the QP was acceptable and the QO was generally not acceptable.

4   Discussion

The main objective of this experiment was to evaluate the quality of radioed speech in noise using two integrated hearing protection headsets, and compare them to a standard radio headset that does not provide hearing protection. A secondary objective was to obtain feedback from the users on the headsets such that subjective user ratings could be obtained. The results show that for the MRT, subjects performed the best using the SH (89%) followed by the QP (83%) and then the QO (70%). Performance was similar for the SPIN, with average scores of 93% for the SH, 87% for the QP and 70% for the QO. Performance on both of the speech intelligibility tests was significantly better using the SH than both the QP and QO. However, the mean user acceptance score was the highest for the QP, followed closely by the SH. Both were relatively much higher than the QO. The largest difference in ratings for the QP and SH was given for "annoyance due to ambient noise." The QP was given a better rating because of the integrated hearing protection. Given that military personnel will be required to wear hearing protection in most, if not all, operational environments, of the three headsets tested the QP provided the best combination of speech quality, hearing protection and usability.

Because integrated hearing protection headsets such as the QP are expensive, it may not be practical to use them in all scenarios. It is important to consider lower-cost solutions. One possible solution is to use the PRR in combination with an earplug. Two types of earplugs that have been evaluated in previous studies are the E-A-R[®] Combat Arms and the Surefire EP3 Sonic Defender[TM] (Abel and Lam, 2004; Abel and Nakashima, 2008).

The E-A-R[®] Combat Arms hearing protector is comprised of two plugs, attached end-to-end. One plug provides conventional, level-independent sound attenuation. The other plug contains and orifice that allows low-level sounds to pass but impedes high-level impulse noise (e.g., from blasts or gunfire). The Surefire EP3 Sonic Defender[TM] offers a similar capability through the use of a cap that can be left open or closed to expose or block the orifice (Figure 3). The plugs can be worn underneath a communication headset earcup with the orifices exposed to allow the user to hear the radio traffic. A pilot test was done with a single pair of subjects using the standard headset in combination with these earplugs. The earplugs were worn in the level-dependent mode (orifice open for the Surefire, yellow plug inserted for the Combat Arms). The results suggested that subjects may perform the same or better with the addition of earplugs (Table 4). It may be of interest to further investigate speech intelligibility using the standard headset in combination with different types of earplugs.
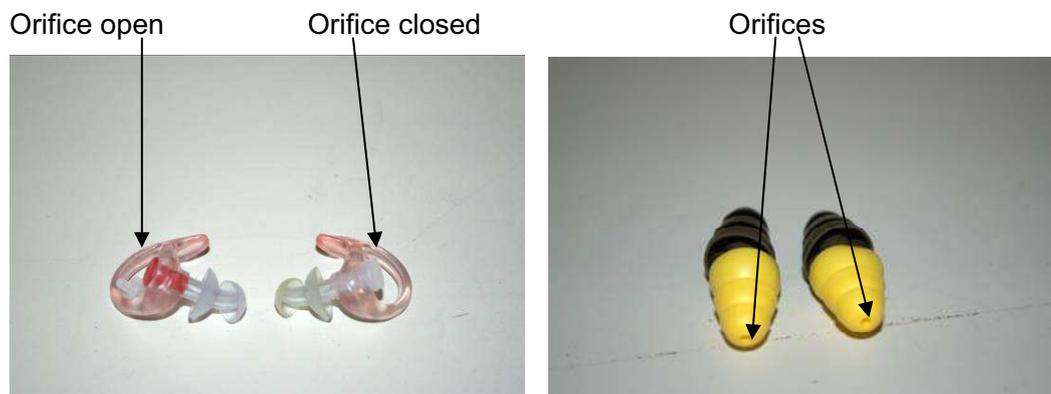
Figure 3: Left – Surefire EP3 Sonic Defender[TM] earplugs; Right – E-A-R[®] Combat Arms earplug.

Table 4: Results for pilot test using earplugs for a single pair of subjects.

	MRT (% correct)			SPIN (% correct)		
	SH	E-A-R® Combat Arms	Surefire EP3 Sonic Defender™	SH	E-A-R® Combat Arms	Surefire EP3 Sonic Defender™
Subject A	78	84	88	78	98	100
Subject B	92	96	98	92	98	96

5 Conclusion

The highest scores on the MRT and SPIN tests in noise were obtained using the standard PRR headset (SH), followed by the QuietPro® (QP) and the QuietOps™ (QO). User comments on the questionnaire indicated preference for SH, with QP being acceptable and QO being unacceptable. Total user acceptance rating scores were highest for the QP, followed closely by the SH. Both had relatively higher scores than the QO. Given that hearing protection will be required in most operational environments, the QP provided the best combination of speech quality, hearing protection and usability. If the QP is not an affordable option, it may be possible to obtain a similar level of performance with the combination of level dependent earplugs and the SH. This option should be further investigated.

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Annex A   Sample: Modified Rhyme Test

Modified Rhyme Test   Form_____ Version_____
Speaker Sub no.: _____   Listener Sub no.: ____
Date: _____   Headset_____

1	but bug bus / buff bun buck	14	map mat math / mad mass man	27	wed fed bed / led shed red	40	cake came cave / cane case cape
2	kin kid kick / king kit kill	15	hop cop shop / mop pop top	28	sane sake safe / save same sale	41	fang bang hang / sang gang rang
3	peak peach peas / peal peace peat	16	sack sad sap / sag sat sass	29	pit pin pig / pill pick pip	42	law saw paw / jaw raw thaw
4	dig wig big / fig pig rig	17	say pay may / gay way day	30	heel peel keel / feel eel reel	43	rake rate ray / raze race rave
5	fold sold gold / hold cold told	18	heath heave heap / heat heal hear	31	toil boil foil / coil oil soil	44	dip dim din / dill did dig
6	kick lick sick / tick wick pick	19	tame came fame / same name game	32	fig fizz fit / fib fin fill	45	tear teal teak / team tease teach
7	path pack pass / pat pad pan	20	page pane pace / pave pale pay	33	mark bark dark / lark hark park	46	tin fin sin / win pin din
8	beat beak beach / beam bean bead	21	dust gust must / bust just rust	34	bash bat ban / back bath bad	47	seethe seek seen / seed seep seem
9	pot hot lot / not tot got	22	pun puff pup / pub pus puck	35	will hill kill / bill fill till	48	run bun fun / sun nun gun
10	fit hit bit / sit kit wit	23	then den ten / pen hen men	36	pale sale bale / gale male tale	49	neat beat seat / meat feat heat
11	sup sub sud / sum sun sung	24	cuss cud cup / cut cub cuff	37	duck dud dung / dun dug dub	50	lip hip dip / sip rip tip
12	dent tent rent / went sent bent	25	hook shook book / took cook look	38	sit sip sill / sick sin sing		
13	best west nest / vest test rest	26	late lake lay / lame lane lace	39	tack tan tab / tang tam tap		

Annex B   Sample: Speech Perception in Noise (SPIN)
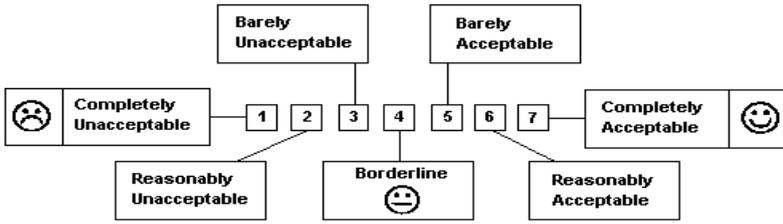
Form # -1 of the Revised SPIN Test (12/83)

Sub no._____   Marker_____   Date_____
#C-High_____   #C-Low_____

1. His plans meant taking a big <u>RISK</u>.   H
2. Stir your coffee with a <u>SPOON</u>.   H
3. Miss White won't think about the <u>CRACK</u>.   L
4. He would think about the <u>RAG</u>.   L
5. The plow was pulled by an <u>OX</u>.   H
6. The old train was powered by <u>STEAM</u>.   H
7. The old man talked about the <u>LUNGS</u>.   L
8. I was considering the <u>CROOK</u>.   L
9. Let's decide by tossing a <u>COIN</u>.   H
10. The doctor prescribed the <u>DRUG</u>.   H

11. Bill might discuss the <u>FOAM</u>.   L
12. Nancy didn't discuss the <u>SKIRT</u>.   L
13. Hold the baby on your <u>LAP</u>.   H
14. Bob has discussed the <u>SPLASH</u>.   L
15. The dog chewed on a <u>BONE</u>.   H
16. Ruth hopes he heard about the <u>HIPS</u>.   L
17. The war was fought with armored <u>TANKS</u>.   H
18. She wants to talk about the <u>CREW</u>.   L
19. They had a problem with the <u>CLIFF</u>.   L
20. They drank a whole bottle of <u>GIN</u>.   H

21. You heard Jan called about the <u>VAN</u>.   L
22. The witness took a solemn <u>OATH</u>.   H
23. We could consider the <u>FEAST</u>.   L
24. Bill heard we asked about the <u>HOST</u>.   L
25. They tracked the lion to his <u>DEN</u>.   H
26. The cow gave birth to a <u>CALF</u>.   H
27. I had not thought about the <u>GROWL</u>.   L
28. The scarf was made of shiny <u>SILK</u>.   H
29. The super highway has six <u>LANES</u>.   H
30. He should know about the <u>HUT</u>.   L

31. For dessert he had apple <u>PIE</u>.   H
32. The beer drinkers raised their <u>MUGS</u>.   H
33. I'm glad you heard about the <u>BEND</u>.   L
34. You're talking about the <u>POND</u>.   L
35. The rude remark made her <u>BLUSH</u>.   H
36. Nancy had considered the <u>SLEEVES</u>.   L
37. We heard the ticking of the <u>CLOCK</u>.   H
38. He can't consider the <u>CRIB</u>.   L
39. He killed the dragon with his <u>SWORD</u>.   H
40. Tom discussed the <u>HAY</u>.   L

41. Mary wore her hair in <u>BRAIDS</u>.   H
42. She's glad Jane asked about the <u>DRAIN</u>.   L
43. Bill hopes Paul heard about the <u>MIST</u>.   L
44. We're lost so let's look at the <u>MAP</u>.   H
45. No one was injured in the <u>CRASH</u>.   H
46. We're speaking about the <u>TOLL</u>.   L
47. My son has a dog for a <u>PET</u>.   H
48. He was scared out of his <u>WITS</u>.   H
49. We spoke about the <u>KNOB</u>.   L
50. I've spoken about the <u>PILE</u>.   L

Annex C   Questionnaire

<table>
<tr><td colspan="2" style="background-color:yellow"><p align="center">Effects of Integrated Hearing Protection Headsets on the Intelligibility of Radio Communications</p></td></tr>
<tr><td colspan="2">Subject ID:</td></tr>
<tr><td colspan="2">Date:</td></tr>
<tr><td colspan="2">System Used (circle one):   PRR   Nacre QuietPro   Silynx QuietOps</td></tr>
</table>

Rate The Following Features:	User Acceptance Rating							Comments:
	1	2	3	4	5	6	7	
Overall ease of use	O	O	O	O	O	O	O	
PTT (push-to-talk) button ease of use	O	O	O	O	O	O	O	
Earphone / Headset comfort	O	O	O	O	O	O	O	
Speech fidelity (i.e. was the speech distorted?	O	O	O	O	O	O	O	
Clarity of communication (i.e. was the channel noisy?)	O	O	O	O	O	O	O	
Continuity of communication (i.e. was the speech broken?)	O	O	O	O	O	O	O	
Annoyance due to ambient noise	O	O	O	O	O	O	O	
Overall Rating	O	O	O	O	O	O	O	

List of symbols/abbreviations/acronyms/initialisms

ANOVA	Analysis of Variance
ANR	Active Noise Reduction
ANSI	American National Standards Institute
CF	Canadian Forces
CVC	Consonant-Vowel-Consonant
dB HL	Decibels, Hearing Level
dBA	Decibels, A-weighted
DRDC	Defence Research & Development Canada
HPD	Hearing Protection Device
Hz	Hertz
IHPH	Integrated Hearing Protection Headset
kHz	Kilohertz
LFCA	Land Force Central Area
MRT	Modified Rhyme Test
PRR	Personal Role Radio
QO	Silynx QuietOps™ headset
QP	Nacre QuietPro® headset
SH	Standard Headset for Personal Role Radio
SPIN	Speech Perception in Noise test

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Effects of integrated hearing protection headsets on the quality of radio communications (U)
Effets des casques d'écoute munis d'un dispositif intégré de protection de l'ouïe sur la qualité des communications radio (U)

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Ann Nakashima; Sharon M. Abel

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(U) The speech intelligibility of a personal role radio (PRR) with integrated hearing protection headsets (IHPH) was investigated. The standard PRR communication headset is comprised of a one−sided earcup and a boom microphone, and does not provide hearing protection. IHPH devices provide simultaneous hearing protection, communication and enhanced hearing capability. Two different tests of speech intelligibility were used (modified rhyme test [MRT] and speech perception in noise [SPIN]) to evaluate the quality of radioed speech over the standard PRR headset (SH), the Nacre QuietPro® (QP) and the Silynx QuietOpsTM (QO). The highest scores on the MRT and SPIN tests in background noise were obtained using the SH, followed by the QP and the QO. However, the QP was given a higher total user acceptance rating score than the SH. Both the QP and SH were rated relatively higher than the QO. Given that hearing protection will be required in most operational environments, the QP provided the best combination of speech quality, hearing protection and usability.

(U) L'intelligibilité de la parole en provenance d'un poste radio personnel (PRR) muni de casques d'écoute avec dispositif intégré de protection de l'ouïe (DIPO) a fait l'objet d'une évaluation. Le casque d'écoute réglementaire avec microphone dont est équipé le PRR se compose d'une seule coupelle à oreille et d'un microphone monté sur tige et n'offre aucune protection de l'ouïe. Les DIPO offrent à la fois protection de l'ouïe, capacité de communication et capacité auditive accrue. Deux tests différents d'intelligibilité de la parole (le test MRT anglais de rimes modifiées et le test SPIN anglais de perception de la parole en présence de bruit) ont servi à évaluer la qualité de la sortie de parole sur le casque d'écoute réglementaire du PRR (casque réglementaire), le casque Nacre QuietPro® (QP) et le casque Silynx QuietOpsTM (QO). Dans le cas du MRT et du SPIN administrés avec bruit de fond, le casque réglementaire a affiché les meilleurs résultats, suivi du casque QP et ensuite du casque QO. Le casque QP a obtenu un meilleur résultat total que le casque réglementaire en ce qui concerne l'acceptation par l'utilisateur. Le casque QP et le casque réglementaire ont obtenu tous les deux un résultat relativement supérieur à celui du casque QO. Étant donné que la plupart des environnements opérationnels exigeront un dispositif de protection de l'ouïe, le casque QP offre la meilleure option combinant qualité de la parole, protection de l'ouïe et facilité d'emploi.

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(U) hearing, radio communications, hearing protection, speech intelligibility

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