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Communication in military environments: Influence of noise, hearing protection and language proficiency

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ABSTRACT

Military training and international operations require different nationalities to communicate in a common language, where there are potential challenges with non-native (L2) speech communication. An experiment of speech communication in military noise was conducted for co-located (face-to-face [F2F]) and distributed (using communication headsets) talker-listener pairs. Half of the twenty-four participants were monolingual English speakers (native group, NA) and the remaining half had obtained English fluency after the age of eight years (non-native group, NN). Two tests of speech understanding were used: the Modified Rhyme Test (MRT) and the Speech Perception in Noise test (SPIN). In the F2F condition, the participants wore a communication headset (earmuff) with the power off for occluded listening. Three levels of armoured vehicle noise were used, 55, 60 and 65 dBA, for speech-to-noise ratios ranging from −10 to +5 dB. In the radio condition, the pairs were separated by a visual barrier and used the communication headset for the tests in 80 dBA armoured vehicle noise. The results showed that the NN group had difficulty with the SPIN test in the radio and F2F conditions. This result was attributed to the open-response set of the SPIN. Headset occlusion likely contributed to the lower scores for the NN listeners in the F2F condition. There was a main effect of talker for the MRT in the F2F and radio conditions, and for the SPIN in the radio condition, suggesting that foreign accent reduced the intelligibility for both the NA and NN groups. The results were surprising considering the high L2 proficiency of the NN group. Training methods for improving L2 communication in operational settings should be further investigated.

1. Introduction

Although there has been extensive research on speech communication in laboratory, classroom and industrial settings, military operational environments present a number of unique challenges that remain unresolved. Continuous noise levels can be in excess of 100 dBA in military aircraft [1,2] and armoured vehicles [3]. In high-noise environments where hearing protection devices (HPDs) are required, communication by radio or face-to-face may be compromised. HPDs must not only provide adequate protection from noise, but also allow soldiers to communicate and maintain situational awareness. To further complicate the problem, during international operations, there may be a requirement to communicate with allied forces in a common language where fluency or accent is problematic for one or more participants.

Speech communication in noise has historically been studied in the context of (1) white or pink noise, (2) speech-shaped noise or (3) speech babble. In addition, the noise levels tend to be relatively low to facilitate manageable speech-to-noise ratios (SNR) [4], providing little insight into ways to enhance communication in noisy military operational environments. For these scenarios, the use of communication headsets must be considered. Communication headsets with integrated hearing protection provide the advantage of attenuating ambient noise while feeding radio traffic directly to the ear. This not only allows protection from the ambient noise, but also facilitates the understanding of radioed speech at lower at-ear presentation levels. A large study of communication headset use in workplaces found that the preferred SNR for at-ear speech to ambient noise level was about +12 to +15 dB when headsets with little or no attenuation were used. By contrast, the preferred SNR was −5 to 0 dB when noise-reducing headsets were used [5]. Military-specific devices, sometimes called Tactical Communications and Protection Systems (TCAPS) [6], have been used in recent years for studies of speech understanding in noise [7–9]. As technology evolves, TCAPS have the potential to improve both face-to-face and radio communication in noise for many users. For example, the use of signal processing algorithms to adaptively improve the SNR in communication headsets has been explored by Brammer et al. [10].

When HPDs or TCAPS are worn in noisy environments, there may still be a requirement to listen to face-to-face conversation or other

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speech that is not presented through the radio. Abel et al. [11–13] conducted a series of studies looking at auditory overload in a simulated mobile command post environment. In the command post, the operator is required to attend to multiple radio channels and an intercom system from an external loudspeaker. The experiments showed that while the participants were able to respond correctly to messages over the radio, they had difficulty with the messages coming from the external loudspeaker. This was attributed to the spectrum of the background noise (recorded armoured vehicle noise) and to the occlusion effect of the headset. With these two factors combined, the messages from the loudspeaker reaching the ear were lower than the levels of background noise at speech frequencies [11]. The studies illustrate that both the spectrum of the background noise and HPD occlusion must be considered when studying speech communication in noise.

The challenges of speech communication in noisy conditions are further exacerbated for those who are listening to a foreign language. A comprehensive review has shown that understanding and learning of a second language (L2) are influenced by factors including native language (L1), age of acquisition, and amount of exposure to L2. Furthermore, native-like proficiency is highly unlikely if L2 is learned after childhood [4]. L2 candidates have to deal with limited L2 vocabulary, phonemic perception confusion and competing L1 words. This causes more uncertainty at all levels of processing for the L2 listener. A 2002 survey found that 42% of Canadian Armed Forces (CAF) used both official languages (French and English) [14]. It is therefore of interest to study non-native communication not only for international operations, but also for routine CAF training operations where communication can occur in one or both official languages.

Mild-to-moderate hearing impairment is an additional challenge that is of particular relevance to military populations. There are very few published studies that combine any or all of hearing loss, HPDs, radio communication and non-fluency. One study showed that the use of HPDs put hearing-impaired listeners at a significant disadvantage compared to normal-hearing participants when listening to ambient speech (non-radioed). Participants who were both hearing-impaired and non-fluent were at a further disadvantage [15]. Giguere et al. found that hearing-impaired participants benefited from level-dependent HPDs, which allowed the users to increase the volume of ambient speech that was transmitted to the ear [9]. In a study of radio communication using non-native and hearing-impaired participants, it was found that hearing-impaired participants performed at a similar level as normal-hearing participants. However, non-native participants obtained lower scores than both the normal-hearing and hearing-impaired groups [27].

The current study was designed to investigate communication in noise between monolingual English-speaking participants and non-native English speakers with different L1s. Two tests of speech understanding were used for face-to-face (F2F) and radio communication using a radio headset with integrated hearing protection in recorded armoured vehicle noise. We hypothesize that (1) non-native participants will achieve lower speech understanding scores than native speakers for all conditions, (2) all participants will have lower scores when listening to a non-native talker compared with listening to a native talker, and (3) higher background noise will cause lower scores, especially for non-native speakers.

2. Materials and methods

2.1. Participants

Ethics approval was obtained from the Human Research Ethics Committee (HREC) of Defence Research and Development Canada (DRDC). Twenty-four men and women, military and civilian, volunteered as participants. Half of the participants (six males and six females) were native monolingual English speakers (NA) and half (six males and six females) were non-native speakers (NN) who acquired fluency in English after the age of 8 years (self-reported). The NA group was restricted to monolingual English speakers because it has been shown that bilinguals may experience difficulty understanding speech in noise due to interference from their second language, even if they were bilingual from an early age. The NN group was restricted to English language acquisition after early childhood because this has been shown to adversely affect speech understanding in noise [16]. English language competency was not objectively tested, although all participants were employed in English-language working environments. The average age was 34.0 ± 9.3 years. Language background was obtained from each participant using the Language Experience and Proficiency Questionnaire (LEAP-Q) [17].

All participants were tested for normal hearing levels (20 dB HL or less at 500, 1000, 2000 and 4000 Hz) by Bekesy audiometry. The use of hearing-impaired participants would have been relevant to the targeted CAF population. However, in order to limit the number of conditions, selection was restricted to normal-hearing participants.

2.2. Experimental protocol

The experimental sessions were conducted in the Noise Simulation Facility, a large, semi-reverberant room ($10.55 \times 6.10 \times 3.05\ m^3$), located at Defence Research and Development Canada, Toronto Research Centre. Of the studies that were reviewed earlier, most used 0 dB SNR in white and speech-shaped noise (energetic masking) or speech noise background (informational masking) [4]. We chose to use a background noise that was more relevant to the CAF environment. The background noise was recorded inside a CAF light armoured vehicle (LAV III) at the driver position [3]. The level of the noise was 97 dBA in situ, but it was presented at lower levels for this study as described below.

An earmuff-style TCAPS device (3M™ Peltor™ LiteCom Plus [3M, St. Paul, MN]) was used for this study. The insertion loss of the muff was measured using a 45CB acoustic text fixture (GRAS Sound and Vibration, Denmark) in 102 dBA pink noise, according to the American National Standards Institute/Acoustical Society of America (ANSI/ASA) S12.42-2010 passive insertion loss procedure [18].

Each participant completed two experimental sessions in pairs, in which they alternated as a talker and listener. The NA participants were paired with another NA in one session and an NN in the other session. Similarly, the NN participants were paired with an NN in one session and an NA in the other. Thus there were four groups of talker-listener pairs: NA-NA, NA-NN, NN-NA and NN-NN. The linguistic backgrounds of the NN-NN pairs were mismatched to avoid a possible interlanguage intelligibility benefit [19]. In addition, since conflicting results have been reported in the literature for intelligibility of female versus male speech [1,20], participant pairs were restricted to same-gender.

The twenty-four participants in the four talker-listener groups were presented two tests of speech intelligibility: the Modified Rhyme Test (MRT) [21] and the Speech Perception in Noise Test (SPIN) [22]. The closed set MRT has been recommended for measuring speech intelligibility over communication systems [23]. For each condition, the talker read through a list of 50 words, with each preceded by the carrier phrase “The word is ___.” The listener circled the word they heard on the response sheet, of a possible six answers for each word. There are three different lists of 50 words for the MRT, with six possible answers, making a total of 18 list variants by changing the target word that is read by the talker. The open set SPIN assesses recognition of both high-predictability (contextual cues provided) and low-predictability (no contextual cues) final words in sentences. The talker read through a list of 50 sentences for each condition, and the listener wrote the last word of each sentence on the response sheet. There are eight different lists of 50 sentences for the SPIN test.

The MRT and SPIN tests were administered for two modes of communication: F2F and radio. The F2F condition was used to represent co-located soldiers in the field, wearing hearing protection, in