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Ann Nakashima
Sharon M. Abel
Ingrid Smith

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

Ann Nakashima*, Sharon M. Abel, Ingrid Smith

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A B S T R A C T

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 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 moderate background noise (e.g., in the vicinity of an idling or travelling armoured vehicle). The talker and listener were seated facing each other at the ends of a two-meter long table. There was no visual barrier between the pair, so lip-reading was possible. The headset was worn by each participant with the radio transmission turned off. Participants were instructed to maintain a "normal" voice level (i.e., not raised) of 55–60 dBA; this was practiced during a training run held prior to the experimental sessions. Background noise levels of 55, 60 and 65 dBA were used, giving SNR in the range of −10 to +5 dB.

The radio condition was used to represent communication between distributed soldiers in the field. A visual barrier was placed in the middle of the table so that the participants could not lip-read. The headset was turned on and the radio channel was used for communication. The background noise was presented at 80 dBA, high enough to limit hearing of ambient speech, such that the talker could only be heard through the radio channel. The talker used the push-to-talk mode to transmit the MRT word and carrier phrase ("the word is __") or the SPIN sentence to the listener. Each participant pair alternated being a talker and a listener for each of the four conditions (three F2F and one radio), using a total of eight MRT and SPIN lists per session. None of the MRT or SPIN list variants were used more than once per session. The order of the conditions (F2F and radio) and background noise levels (F2F condition) were counterbalanced across listeners. For all testing, guessing was encouraged and no feedback was given about the correctness of responses.

2.3. Data analysis

LEAP-Q responses were used to confirm group assignment and characterize the demographic of the participants. The dataset for each of the twenty-four listeners consisted of the percentage correct on the MRT and SPIN lists, for each of the F2F and radio conditions. Repeated measures analyses of variance (ANOVA) were applied to the percentage correct for each of the tests, to evaluate the significance of differences due to talker-listener pairings between groups, gender within groups and background noise level in the F2F condition. The effect of initial versus final consonant contrast was assessed for the MRT and the effect of high- and low-predictability sentences was assessed for the SPIN test. Non-parametric analysis was used for gender subgroups within the NA and NN groups.

3. Results

3.1. LEAP-Q results

The LEAP-Q responses for the NN group are summarized in Table 1. The L1s reported by the NN group were French, Chinese, Mandarin, Serbian, Spanish and Russian. Two participants who reported French as their L1 reported living in Canada for 37 and 30 years, but with 7 and 14 years of school and/or work in English, respectively. Therefore, the distinction between number of years in Canada and the years of school and work (combined) in English is important. The possible self-ratings of spoken, reading and writing fluency were from 0 to 10 with 10 being the highest fluency. For the question about accent perceived by others, a response of 0 corresponded to never and 10 to always. The average is not given in Table 1 due to the range of responses. Responses of 3, 5, 7 and 9 were given once each, with the remaining eight responses being 0 and 1.

Table 1
Summary of selected LEAP-Q responses for the NN participant group (n = 12).

Age began learning English	10.9 ± 3.7 years
Age English fluency obtained	21.4 ± 10.6 years
Number of years in country	17.7 ± 9.3 years
Years of school and/or work in English	13.7 ± 6.7 years
Self-rating of fluency (spoken)	7.8 ± 1.2
Self-rating of fluency (reading)	8.6 ± 0.6
Self-rating of fluency (writing)	8.8 ± 0.7

3.2. Background noise and headset occlusion

Fig. 1 shows the room background noise in quiet and with vehicle noise at 60 dBA, and sample female and male speech spectra that were recorded in the room in quiet while reading a phonetically balanced passage. The speech spectra are shown to estimate the SNR in vehicle noise. The four participants were chosen because they were native English speakers and represented a range of ages: 20 (male), 36 (female), 54 (female) and 61 (male). On average, the SNR in vehicle noise were about +3 dB, −15 dB, −3 dB and −4 dB at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz, respectively.

The female and male speech spectra, this time averaged by gender, are shown in Fig. 2 with the insertion loss of the headset. The insertion loss values were subtracted from the speech spectra to estimate the occluded speech spectra. The overall insertion loss of the earmuff headset on the A-weighted background noise level was 24 dB. Occluded speech frequencies above 800 Hz are reduced to less than 10 dB.

3.3. F2F results

All results are presented as the percentage correct obtained by listeners. Main effects are reported as averages across all listeners and talkers (NA and NN combined). Where there was a main effect of talker, the average percentage correct obtained by the listeners are separated for pairings with NA versus NN talkers.

An ANOVA on the F2F MRT results showed main effects of background noise level (81.1% at 55 dBA, 78.3% at 60 dBA and 72.8% at 65 dBA; $p < .001$), talker type (79.6% for NA talkers and 75.2% for NN talkers; $p < .04$) and contrasting consonant position (82.8% for initial consonant and 72.0% for final consonant; $p < .03$). The results for percentage correct by background noise level are shown in Fig. 3, separately for initial and final contrasting consonant words and grouped by talker type. There was a significant interaction of talker by consonant position (estimated marginal means 83.4% for initial and 75.8% for final consonant for NA talkers and 82.3% for initial and 68.2% for final consonant for NN talkers; $p < .03$) and background noise level by gender ($p < .02$). For male listeners, the results were 78.5%, 79.8% and 70.9% for 55, 60 and 65 dBA, respectively, versus 83.8%, 76.7% and 74.8%, respectively, for the females.

For the F2F SPIN, an ANOVA showed main effects of background noise level (68.4%, 63.5% and 55.7% at 55, 60 and 65 dBA, respectively; $p < .001$) and predictability (72.6% for high predictability sentences and 52.5% for low; $p < .001$). The results for percentage correct by background noise level are shown in Fig. 4, separately for high and low predictability sentences and grouped by talker type. There was also a between-subjects effect of listener (70.9% for NA and 54.1% for NN; $p < .001$). There was a significant interaction of talker by listener gender (female listeners: 65.9% for NA and 68.9% for NN talkers; male listeners: 66.3% for NA and 49.0% for NN talkers).

3.4. Radio results

The results of the MRT and SPIN for the radio condition are summarized in Table 2. For the MRT, an ANOVA showed main effects of talker (87.2% for NA and 77.5% for NN; $p < .003$) and contrasting consonant position (87.1% for initial and 77.6% for final; $p < .001$). There was a significant interaction of talker by gender (for males: 90.3% for NA and 74.0% for NN talkers; for females: 84.0% NA and 81.0% for NN talkers). An ANOVA on the SPIN results showed main effects of talker (84.2% for NA and 76.0% for NN; $p < .02$) and predictability (88.7% for high predictability sentences and 71.5% for low; $p < .01$). There was a between subjects effect of listener (86.4% for NA and 73.8% for NN; $p < .01$).

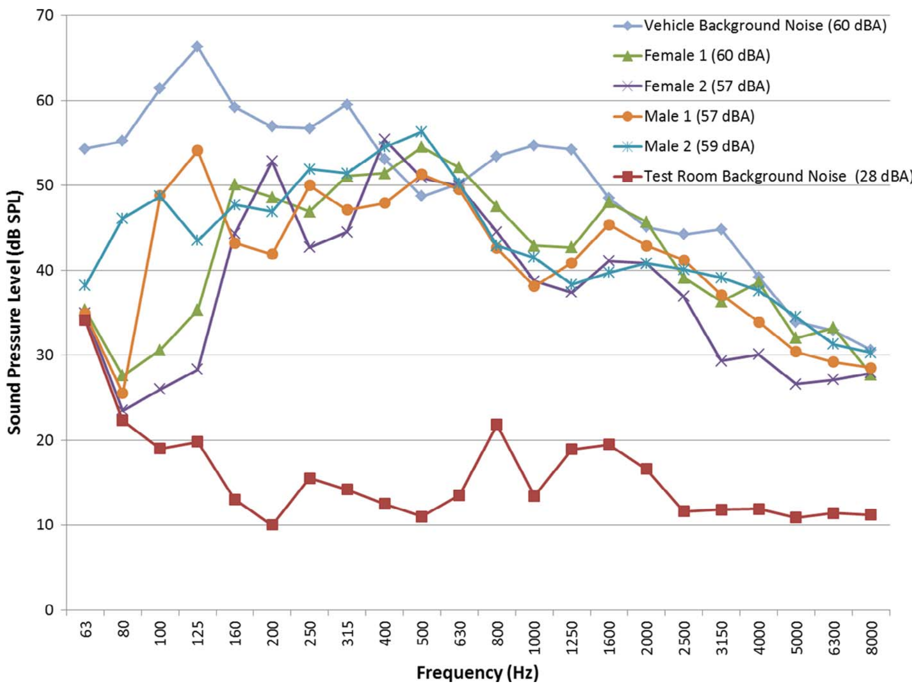

Fig. 1. Background noise of the test room in quiet and in 60 dBA vehicle noise, and sample female and male speech spectra that were recorded in the test room in quiet.

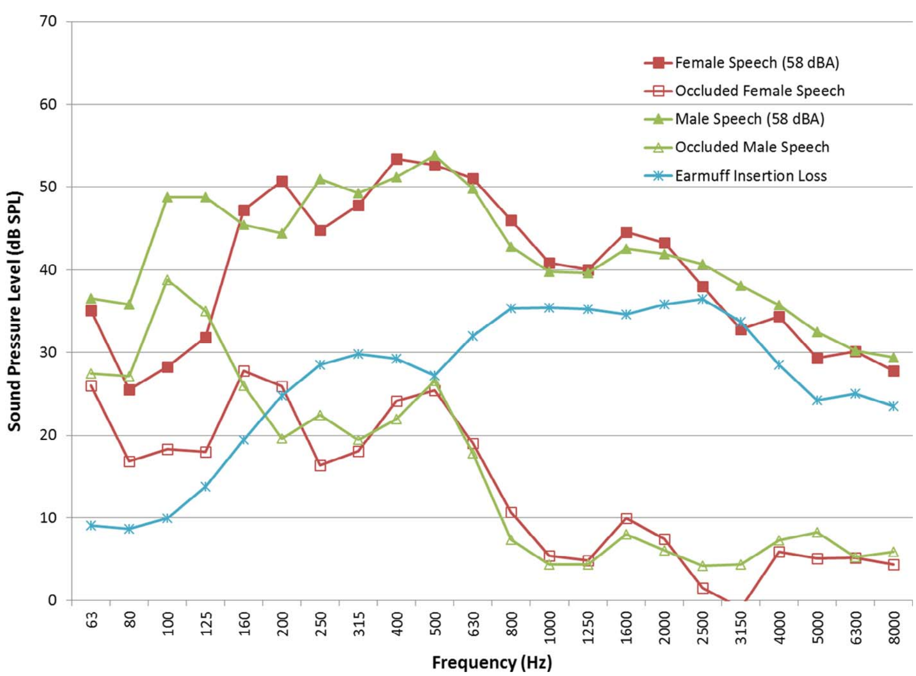

Fig. 2. Sample female and male speech spectra in the test room, before and after headset occlusion. The insertion loss of the headset is shown for reference.

4. Discussion

4.1. F2F condition: signal-to-noise ratio and occlusion

In the F2F condition, there were main effects of background noise level for both the MRT and SPIN. As expected, speech intelligibility decreased as the background noise level increased. A significant between-subjects effect was found for NN listeners on the SPIN (54.1% vs. 74.9% for NA listeners). Headset occlusion should be considered in the interpretation of this result. The communication headset provided about 24 dB overall insertion loss. Importantly, across the speech frequencies from 500 to 2000 Hz, the insertion loss values were about 27–35 dB, while the low frequency insertion loss was minimal (Fig. 2). For ambient listening (F2F communication), the muff acts like a low-pass filter to both the noise and speech. Fig. 2 illustrates that the muff reduces speech frequencies down to 10 dB or less above 800 Hz, which is close to threshold of hearing for a normal-hearing listener. Previous studies have shown that wearing an HPD does not affect speech understanding for normal-hearing listeners because the overall SNR is unchanged [24]. However, non-fluent listeners and those with hearing loss can be at a disadvantage [15]. The results suggest that despite the headset occlusion, NN listeners can perform at the level of NA listeners when the response set is closed (MRT), but not with an open response set (SPIN). This result was seen despite the high proficiency of the NN group.

Interestingly, there was no between-subjects effect for the MRT, but there was a main effect of talker (79.6% for NA vs. 75.2% for NN talkers), suggesting a slight effect of foreign accent. The small, but

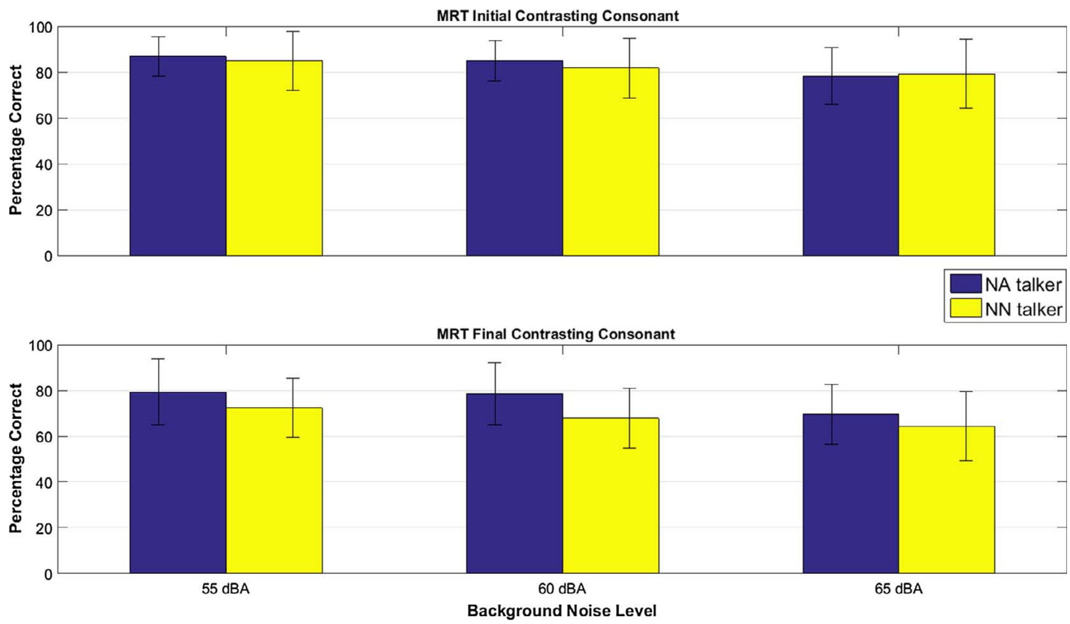

Fig. 3. Results for the F2F condition. Percentage correct for the MRT, presented separately for talker type (NA and NN) and background noise level. The error bars represent standard deviation.

significant main effect of talker for the MRT suggests that foreign accent, however slight, affects speech intelligibility for both NA and NN listeners. This is in agreement with a previous study of non-fluency, hearing loss and communication headset type, which found that both the English-fluent control and the hearing loss groups obtained higher scores on the MRT when listening to fluent talkers than with non-fluent talkers. Non-fluent listeners in the same study had lower MRT scores than the hearing loss group [27].

Table 2
Mean percentage correct and standard deviation for the MRT (by trials with initial and final contrasting consonant) and SPIN (by trials with high and low predictability) for the radio condition.

	NA Talker	NN Talker
MRT initial consonant	90.7 ± 9.2	83.5 ± 10.3
MRT final consonant	83.7 ± 11.7	71.5 ± 17.9
SPIN high predictability	92.5 ± 10.2	84.8 ± 17.6
SPIN low predictability	75.8 ± 16.4	67.2 ± 22.5

4.2. Radio condition: confounding factors

There was a main effect of talker type for both the MRT (87.2% for NA and 77.5% for NN) and SPIN (84.2% for NA and 76.0% for NN) tests

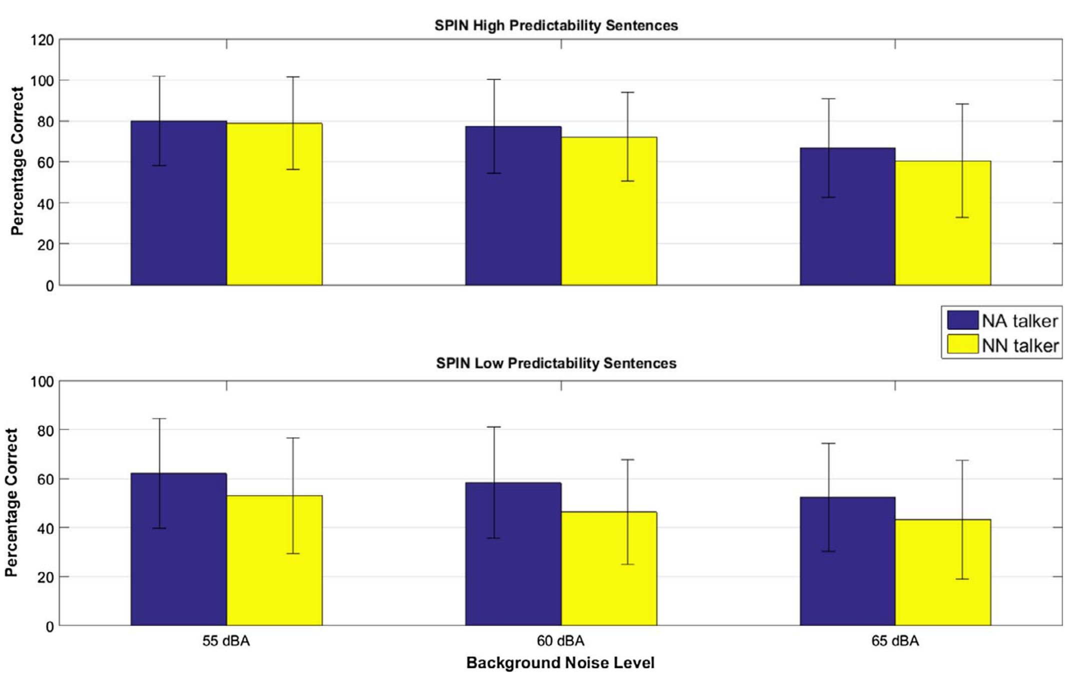

Fig. 4. Results for the F2F condition. Percentage correct for the SPIN, presented separately for talker type (NA and NN) and background noise level. The error bars represent standard deviation.

in the radio condition. The between-subjects effect for listener on the SPIN test (86.4% for NA and 73.8% for NN) suggests that the NN group had difficulty with the open response set. The F2F results were not compared with the radio results in the analysis because there are several confounding factors: different SNRs, potential benefits of lip reading in the F2F condition, headset occlusion in the F2F condition and possible speech distortion in channel for the radio condition. However, it was expected that the participants would achieve higher scores with the radio than F2F because the SNR is higher when the speech is fed directly to the ear. It is possible to estimate the SNR for radioed speech by measuring the at-ear speech level with an acoustic test fixture, but the calculation is complicated by the head-related transfer function of the ear and differences in earmuff fit among the participants [5]. We did not attempt to estimate the SNR, but tried to control it by training the participants to maintain a constant voice level (55–60 dBA) and fixing the headset volume at the maximum. A previous study that used an earlier model of the headset found the gain to be about 10 dB at maximum volume [8].

4.3. Gender effects

The significant interactions of listener gender by background noise level (F2F MRT), and talker type (F2F SPIN and radio MRT) are difficult to interpret due to the limited numbers in each gender subgroup (six in each of the NA and NN groups). In addition, the participants were restricted to same-gender pairs to limit the number of conditions. A previous study showed a slight advantage for perception of final consonant in female pairs compared to male pairs; however, the number of participants was limited [8]. By contrast, male talker-listener pairs obtained higher scores than female pairs when using certain devices in a two-way radio communication study. It was suggested that the higher frequencies of the female voice were poorly transmitted by the frequency-limited microphone of the communication headset [27]. For mixed-gender pairs, the results of previous studies suggest that female talkers may be more intelligible that male talkers, but there was no significance for gender of the listener [1,20]. The mixed results among the previous studies underlines the need for further investigation of gender differences for speech communication.

4.4. Limitations of study design

A distinction between L2 and foreign language (FL) has been made for non-native communication [4]. An L2 is a language that is dominantly present in one's everyday life, whereas an FL is not. For the current study, we can generalize the NN group as L2 based on the LEAP-Q results for number of years of schooling or work in English. Furthermore, the high self-ratings of English ability in reading, writing and speaking indicate a high level of L2 proficiency. For the rest of the discussion, NN will be used to refer to our specific experimental group, and L2 will be used to refer to non-native English speakers in a general sense.

In a comprehensive review of non-native communication studies, it was indicated that one consistent limitation was the lack of realism [4]. Previous studies used carefully controlled laboratory conditions, defined background noise spectra, recorded word lists and closed-response set tests, which do not represent everyday life situations that are faced by non-native communicators. The current study was designed with a military operational environment in mind. The recorded LAV III noise was presented at low levels to facilitate reasonable SNRs (55–65 dBA for F2F and 80 dBA for the radio condition), but the spectrum of the noise was maintained. Informational masking (i.e., speech babble) can also have a negative effect on speech perception in noise [25,26]. However, it was not used here because previous work has shown that combined vehicle and babble noise did not affect performance compared to vehicle noise alone under diotic listening conditions [11].

There were several limitations in this study. When using two-way communication in the study of speech understanding, controlling the speech volume of the talker is a challenge. This is especially true when background noise is used because it is difficult to obtain accurate measurements of the speech levels in low SNR conditions. Although the participants were asked to keep their voice levels at 55–60 dB during the training session, there was some variation in speech levels among participants. Constraining the voice levels is artificial because humans have a tendency to raise their voices in noisy situations (Lombard effect) and lower their voices when HPDs are worn [28]. For the radio condition, other operational noises at more realistic levels could have been used. Open-response set tests are more realistic than closed-set, but they are more difficult to score. When scoring the written responses for the SPIN, it was noted that participants wrote words that were similar-sounding, homonyms, singular or plural versions of the target word. These were marked as being correct. A speech understanding test that uses military-specific language would have been useful for our application. Despite the limitations, our results indicate that even highly proficient L2 individuals may have difficulty communicating in noise, both F2F and over radio, and this has implications for the success of training and international operations.

5. Conclusions and future work

Our first hypothesis was partly confirmed. The NN group obtained lower scores than the NA group on the open-response set test (SPIN), but their scores were not significantly different on the closed-response set test (MRT). There was a between-subjects effect of talker in both the radio and F2F conditions, which confirmed our second hypothesis: all participants had lower scores when listening to a NN talker compared with listening to a NA talker. This result was attributed to foreign accent. Finally, our third hypothesis was partly confirmed: there was a main effect of background noise level in the F2F condition, but it was no worse for the NN group than the NA group.

Since L2 individuals are clearly at a disadvantage for speech communication in noise, perhaps even more so than those with hearing loss [27], it is of interest to investigate ways to improve communication. It has been suggested that trainees should practice their L2 skills under realistic workload conditions to better prepare for operations, and that they should be exposed to English speakers from different regions to increase exposure to linguistic diversity [29]. It has been shown that speech understanding in noise can be improved for both L1 and L2 listeners using a cognitive training regime [30]. Different training methods should be investigated to improve L2 communication in operational settings.

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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.

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Hearing protection; Military noise; Speech understanding; Non-native speech