THE EFFECT OF SENTENCE REPETITION ON SPEECH INTELLIGIBILITY IN NOISE

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1. INTRODUCTION

Good verbal communication is essential to ensure safety in the workplace and active social participation during daily activities. In many situations, however, speech comprehension may be difficult due to hearing problems, the presence of noise or other factors. As a result, listeners must sometimes ask the speaker to repeat what was said in order to understand the complete message. A few early studies indicated that repetition may slightly increase speech intelligibility, primarily for the first repetition [1-3]. However, there is relatively little data available on the exact benefits of this commonly-used strategy for different noise conditions, despite Pollack's early observation that the "*diversity of successive speech and/or noise samples is an important determinant of the improvement in intelligibility with successive presentations*" [4].

The objectives of this research are: (1) to compare the relative benefits of repetition on word intelligibility under continuous and fluctuation noise conditions, and (2) to document the effect of noise conditions on the parameters of the performance-intelligibility (PI) function for sentences spoken once or twice. Intuitively, one can hypothesize that the benefit of repetition on intelligibility may be greater under fluctuating than continuous noise conditions, if independent noise samples are used on the first and second presentations. Under fluctuating noise conditions, the listener may be able to benefit from masking troughs during the repetition to identify speech sounds masked upon the initial presentation. Under continuous noise conditions, speech sounds are uniformly masked across presentations.

2. METHOD

2.1 Subjects

Eighteen French-speaking subjects (10 males, 8 females), aged between 20 and 30 years, participated in the study. Subjects had normal hearing defined by the following criteria: a) air conduction hearing threshold ≤ 15 dBHL between 0.6 and 6 kHz bilaterally; b) normal tympanograms, c) negative otologic history, and (d) score on the Canadian French HINT test [5] within normal.

2.2 Materials

Subjects were presented lists of 20 sentences from the Canadian French HINT test under three different noises selected from the ICRA database [6]: continuous speech-spectrum noise for a male speaker (Noise A), modulated speech-spectrum noise corresponding to a single speaker (Noise B), and modulated speech-spectrum noise corresponding to a group of 6 persons speaking simultaneously (Noise C). They correspond to ICRA1, ICRA5 and ICRA7 noises respectively. Listening tests were carried out at three different S/N ratios for each of the three noises, for a total of 9 experimental conditions per subject. A different list of sentences was chosen for each condition. Lists were counterbalanced across subjects, noises and S/Ns.

2.3 Procedure

The speech lists were so designed that each of the 20 independent sentences was presented twice. After the first presentation, the subject was requested to repeat or guess what was heard and the experimenter scored the number of words correctly identified. The same recorded sentence was then presented a second time and the subject was again requested to repeat what was heard for scoring purposes. It was thus possible to obtain two scores for each experimental condition: a percent intelligibility on the initial presentation of the 20 sentences and a similar score after the second presentation (i.e. repetition). Independent noise samples were used on the first and second presentation of each sentence. Thus, instantaneous noise masking peaks and troughs were not synchronized with the speech waveform upon successive presentations of the same sentence.

3. ANALYSIS AND RESULTS

A simple means of characterizing the effect of repetition was used to interpret the experimental results. If one assumes that the probability of words correctly recognized on the initial presentation is p, then the probability of incorrect recognition is $q=1-p$. If the spoken communication is repeated in the same conditions, and the probabilities of correct and incorrect word recognition remain the same and are independent of the initial presentation, then the joint probability of incorrect word recognition after the repetition is q^2, and the probability of correct recognition is $1-q^2 = p + pq$. The term pq represents the benefit of repetition if the assumptions above hold true. A more general model, $p + \alpha pq$, is obtained by introducing a repetition coefficient α to adjust the contribution from the second presentation to the overall probability of correct recognition ($0 \leq \alpha \leq 1/p$). If α is 0, the second presentation does not improve recognition. If $\alpha = 1$, word recognition is independent of presentation. Figure 1 illustrates the percent word recognition after the second presentation as a function of percent recognition during the first presentation for different coefficients α of the repetition model.

The repetition model can also be used to predict the effect of the second presentation on the shape of the performance-intensity (PI) function in different noise conditions (as determined by different repetition coefficients α). This is illustrated in Figure 2. As can be seen, repetition is expected to decrease the SRT and increase the slope of the PI function, and these effects are more important the larger the repetition coefficient α.

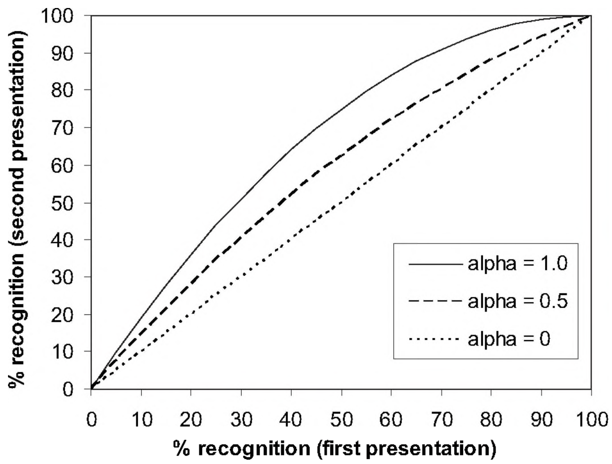

Fig. 1: Repetition effect for different coefficients α (0, 0.5, 1.0) of the repetition model.

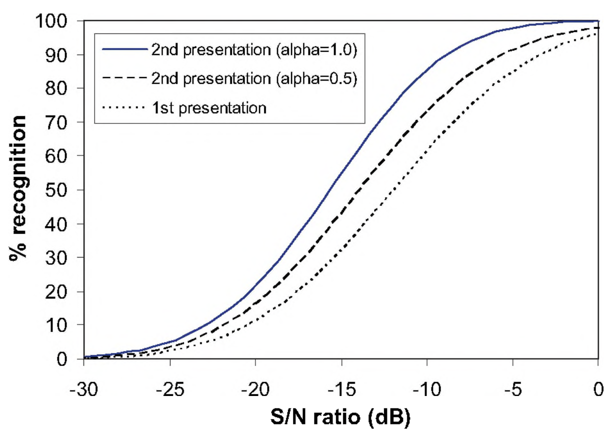

Fig. 2: PI functions for two hypothetical values of the repetition coefficient α in comparison with the PI function for the initial presentation (SRT = -12 dB S/N and slope of 6%/dB).

Table 1 lists the optimal repetition coefficient calculated from an analysis of the experimental data obtained in the three noise conditions used in this study. These coefficients carry the least amount of error between model predictions and the experimental data for each noise. As expected, the continuous speech-spectrum noise (Noise A) exhibits the lowest repetition coefficient α, and the most highly modulated noise (Noise B) exhibits the highest α. In the latter case, the value is very close to 1, indicating statistical independence of the first and second presentations.

The experimental data were also analyzed to extract the SRT and the slope of the PI function in the three noises and two presentation conditions. Table 1 lists the improvement in SRT between the first and second presentations, and the ratio of PI slopes in the three noises conditions. Repetition improves the SRT and increases slightly the slope of the PI function, as expected. The improvement in SRT ranges from 2.0 to 5.4 dB across noises. The PI slope increases by up to 34%. These effects are most pronounced for the most highly modulated noise (Noise B), and least pronounced for the continuous noise (Noise A). Thus, dependence of the repetition effect on noise type is confirmed.

Table 1: Summary of results: repetition coefficient α, difference in SRT between presentations, and ratio of PI slopes (A: continuous noise, B: modulated noise from a single speaker, C: modulated noise from 6 speakers).

Noise	α	$SRT_2 - SRT_1$ (dB)	$Slope_2/Slope_1$
A	0.65	-2.0	0.98
B	0.98	-5.4	1.34
C	0.89	-3.2	1.11

4. CONCLUSIONS

Results show that the benefit of repeating sentences in noise depends on the temporal structure of the noise for normally-hearing listeners. The larger the temporal fluctuations in the noise, the more benefits in intelligibility can be gained by repetition. The experimentation needs to be replicated for a group of hearing-impaired individuals to determine if the main results generalize to this population.

The findings of this study could be useful in a wider context to develop predictive tools to assess speech communication scenarios under various listening conditions [7].

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