Word recognition performance in competing sentence and multitalker babble paradigms in listeners with hearing loss

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The word-recognition performances of 24 listeners with normal hearing and of 72 listeners with hearing loss were evaluated using a single-talker competing message (CM) and a six-talker multitalker babble (MTB). The 50% points were calculated using the Spearman-Kärber equation. The mean 50% point with the CM paradigm was -3.5 dB signal-to-noise ratio (S/N) and was 3.9 dB S/N with the MTB for the listeners with normal hearing. The listeners with hearing loss had a mean 50% point of 11.1 dB S/N with the CM and 13.4 dB S/N with the MTB. For both groups of listeners, the slopes of the psychometric functions were steeper for the MTB paradigms than for the CM material paradigms. These findings suggest that the listeners with hearing loss perform similarly with both noises, whereas the listeners with normal hearing probably achieve a partial release from masking from the valleys in the amplitude modulations of the CM more so than the modulations provided by the MTB.

INTRODUCTION

Several studies have compared recognition performance with different types of competing noise. These studies demonstrated that listeners with normal hearing had better recognition performance with amplitude-modulated noise than with continuous noise (Miller and Licklider, 1950; Dirks *et al.*, 1969; Wilson and Carhart 1969; Wilson *et al.*, 2007). Listeners with normal hearing are able to benefit from the valleys in the modulated noise, resulting in a release from masking. In these noise paradigms that are amplitude modulated, listeners with hearing loss are only able to achieve a partial release from masking in comparison to the release from masking that is achieved by listeners with normal hearing (Bacon *et al.*, 1998; Holma *et al.*, 1997; Wilson *et al.*, 2007).

This study used listeners with normal hearing and listeners with sensorineural hearing loss to compare recognition performances on monosyllabic words using two noises, a single-talker competing message (CM) and a multitalker babble (MTB). Because the CM was produced by one speaker reading sentences and the MTB was produced by six speakers reading passages, the amplitude modulation characteristics of the CM were more extreme than the amplitude modulation characteristics of the MTB. The supposition, therefore, was that both groups of listeners would achieve higher recognition performance in the CM condition than in the MTB condition. Further, the within-

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group difference between the two maskers was expected to be greater for the listeners with normal hearing and for the listeners with hearing loss.

METHODS

Materials

Words-In-Noise (WIN) Test

The WIN test consists of 70 words from the Northwestern Auditory Test No. 6 (NU-6; Tillman and Carhart, 1966) spoken by a female speaker (Department of Veterans Affairs, 2004) that are presented in a six-talker multitalker babble paradigm at seven signal-to-noise (S/N) ratios that range from 24 to 0 dB S/N, in 4-dB decrements (Wilson, 2003; Wilson *et al.* 2003; Wilson and Burks, 2005). Ten words are presented at each SNR with the level of the multitalker babble fixed and the level of the words varied. Performance is scored in terms of both the percent correct at each SNR and the 50% point on the function calculated with the Spearman-Kärber equation (Finney, 1952).

NU No. 6-Competing Message (CM)

The NU No. 6-CM test consists of the 4 lists of NU-6 words (200 words) presented with a single-talker competing message (Department of Veterans Affairs, 2004). Each word of each list was paired and time locked with a corresponding CM that is spoken by a male speaker. The 50 competing sentences for each list were taken from the Modified Bell Telephone Sentences (Fletcher and Steinberg, 1929), 19 of which were modified further to maintain a more continuous airstream through the production of the sentence and to enhance the American dialect (Wilson *et al.*, 1990). For this experiment, each word and the corresponding CM were edited digitally to create the required SNRs, again with the presentation level of the CM fixed and the level of the words varied. To avoid order effects, two randomizations of each 50-word list were devised with each list recorded as two, 25-word lists.

Both the WIN and NU No. 6-CM materials were calibrated to a 1000-Hz pure-tone and recorded on compact disc. The speech and noise were mixed and recorded on one channel and the speech alone was recorded on the second channel for monitoring purposes.

Participants

Twenty-four listeners (mean age = 24.3 years, *SD* = 3.3) with normal hearing participated in the study. The pure-tone thresholds were ≤ 20 dB HL (ANSI, 2004) from 250 to 8000 Hz in octave and inter-octave intervals. Seventy-two listeners with sensorineural hearing loss (mean age = 66.9 years, *SD* = 9.7) also participated in the study. The mean audiogram (and one standard deviation) of the test ear for the listeners with hearing loss is illustrated in Figure 1. To ensure audibility of the test materials, the participants with hearing loss were required to have a pure-tone average (re: 500, 1000, and 2000 Hz) between 25-40 dB HL. All participants had a negative history of middle ear and retrocochlear pathologies.

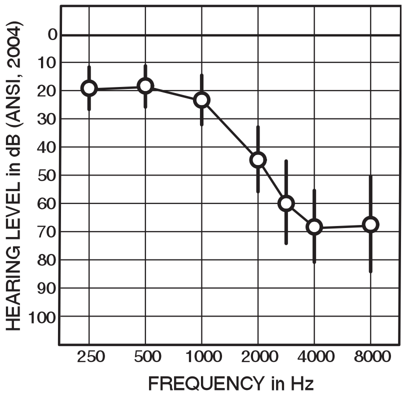

Fig. 1: The average audiogram for the test ear of the 72 listeners with hearing loss is shown along with the standard deviations (vertical bars).

Procedures

After pure-tone testing, the participants completed word recognition testing in quiet at 80 and 104 dB SPL using two half-lists from the NU No. 6 test (List 4; Department of Veterans Affairs, 2004). The two half-lists and the two presentations levels were counterbalanced. Next, the WIN was administered with the level of the babble fixed at 80-dB SPL. Finally, the 32 half lists of the NU No. 6-CM test (4 50-word lists by 4 levels) were administered using a random order with the level of the CM fixed at 80-dB SPL. The test materials were reproduced on a compact disc player (Sony, Model CDP-CE375) routed through an audiometer (Grason-Stadler, Model 61) to a TDH-50P earphone. The right ears of the even-numbered participants and the left ears of the odd-numbered participants were used to avoid any ear effects. The non-test ear was covered with a dummy earphone. All testing was accomplished with the participant seated in a double-walled sound booth. The verbal responses were scored and recorded into a spread sheet.

RESULTS AND DISCUSSION

The word recognition in quiet scores presented at 80- and at 104-dB SPL were 97.7% (*SD* = 2.6) and 96.7% (*SD* = 2.5), respectively, for the listeners with normal hearing and 69.8% (*SD* = 16.3) and 82.0% (*SD* = 12.0), respectively, for listeners with hearing loss. The presentation levels of the words in quiet testing correspond to the levels of the words at the 0- and 24-dB S/N conditions in the WIN paradigm. These data demonstrate that the word stimuli are audible to the listeners at these levels.

Figure 2 is a two-panel graph depicting the psychometric functions for the listeners with normal hearing (top panel) and the listeners with hearing loss (bottom panel) in terms of word recognition performance with the two noise conditions. Percent correct word recognition performance is on the ordinate and S/N ratio in dB is on the abscissa. The filled symbols depict the mean performance on the NU No. 6-CM and the open symbols represent the mean performance on the WIN. The 50% point calculated from the polynomial was -5.2 dB S/N and 3.4 dB S/N for the NU No. 6-CM and for the WIN, respectively, for the listeners with normal hearing and 9.6 dB S/N and 12.5 dB S/N, respectively, for the listeners with hearing loss. These results indicate that listeners with normal hearing perform 8.6 dB better with the CM than with the MTB, whereas the listeners with hearing loss performed only 2.9 dB better with the CM than with the MTB, as expected. These results support previous research demonstrating the listeners with normal hearing are able to benefit from release from masking more so than are listeners with hearing loss. Based on these and other data (e.g., Wilson et al, 2007), it is apparent that listeners with hearing loss are masked equally by a variety of noises regardless of the amplitude-modulation characteristics, whereas listeners with normal hearing obtain progressively more release from masking as the amplitude-modulation characteristics of the noise are exaggerated.

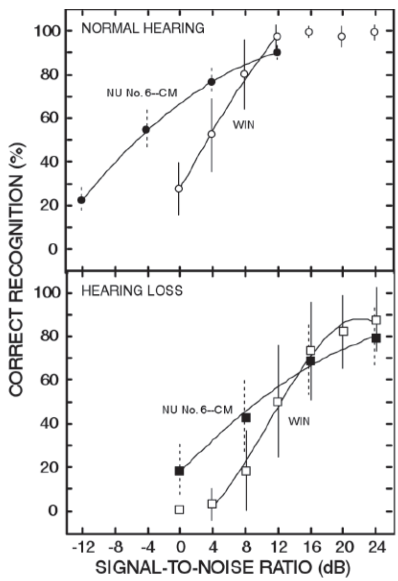

Fig. 2: The mean psychometric functions for the NU No. 6-CM and WIN are shown for listeners with normal hearing (top panel) and for listeners with hearing loss (bottom panel).

The slopes for the functions in Figure 2 from the listeners with normal hearing were 3.6%/dB and 6.5%/dB for the NU No. 6-CM and WIN, respectively, and 2.9%/dB and 6.3%/dB, respectively, for the listeners with hearing loss. Within each group of listeners, the slopes of the NU No. 6-CM were approximately half as steep as the slopes of the WIN functions. The difference in slopes for the NU No. 6-CM and WIN functions indicates that different masking or interference mechanisms were involved with the two noises. The listening "windows of opportunity" in a single-speaker competing message are more frequent and have longer durations than do the "windows of opportunity" encountered with a multitalker babble.

To compare the performance on the WIN with the performance on the NU No. 6-CM, the 50% points were calculated using the Spearman-Kärber equation (Finney, 1952). Figure 3 is a bivariate plot of the level (dB S/N) at which the 50% data points for listeners with normal hearing (circles) and listeners with hearing loss (squares) occurred for the NU No. 6-CM (ordinate) and the WIN (abscissa). The larger filled symbols represent the mean data from the listeners and the diagonal line represents equal performance on both test materials.

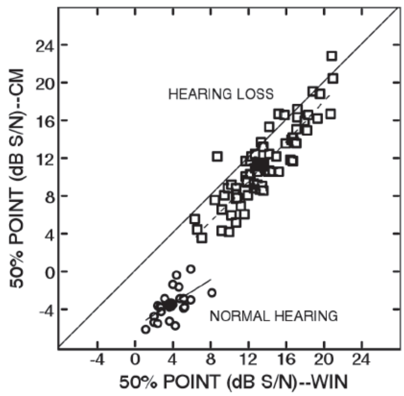

Fig. 3: A bivariate plot of the 50% points calculated with the Spearman-Kärber equation for the 24 listeners with normal hearing (circles) and the 72 listeners with hearing loss (squares) for the Nu No. 6-CM (ordinate) and the WIN (abscissa). The large filled symbols depict the mean datum point for each group of listeners. The diagonal line represents the line of equality and the lines through the datum points represent the best-fit regression.

The datum points for the listeners with normal hearing are located in the lower, left-hand portion of the figure. All the datum points fall below the line of equality, indicating that all listeners with normal hearing had a lower 50% point with the NU No. 6-CM than with the WIN. The datum points also are clustered closely together indicating little variability among these listeners. The mean 50% point for the NU No. 6-CM was -3.5 dB S/N (*SD* = 1.6) and the mean 50% point for the WIN was 3.9 dB S/N (*SD* = 1.6). This 7.4 dB difference demonstrates that listeners with normal hearing are able to take advantage of the valleys in the amplitude modulations of the CM more so than the valleys provided by the MTB.

In comparison to the listeners with normal hearing, the datum points for the listeners with hearing loss are spread, indicating more variability. The majority (*n* = 64) of the datum points are below the line of equality, indicating that most listeners had higher 50% points with the WIN than with the NU No. 6-CM. The mean 50% point for the NU No. 6-CM was 11.1 dB S/N (*SD* = 4.3) and was 13.4 dB S/N (*SD* = 3.5) on the WIN. The listeners with hearing loss had on average a 2.3 dB better 50% point with the CM than with the MTB, which was ~5 dB less of a difference than for the listeners with normal hearing. The dashed line through the datum points is the best fit regression, which had a slope of 1.0. These data suggest that most listeners with hearing loss performed better on the NU No. 6-CM materials, but on average only by 2.3 dB, and that overall, the listeners with hearing loss had equal performance on both materials. Other studies also have shown that listeners with hearing loss are unable to benefit from release from masking with amplitude modulated noise as well as listeners with normal hearing (Bacon *et al.*, 1998; Holma *et al.*, 1997; Wilson *et al.*, 2007).

CONCLUSIONS

In summary, the mean word-recognition performances on the NU No. 6-CM condition was 7.4 dB and 2.3 dB better than on the WIN paradigms for the listeners with normal hearing and the listeners with hearing loss, respectively. For both groups of listeners, the slopes of the functions were steeper for the WIN materials than for the NU No. 6-CM materials. These findings suggest that the listeners with normal hearing probably are able to take advantage of the valleys in the amplitude modulations of the CM more so than the modulations provided by the MTB, whereas the listeners with hearing loss perform similarly with both noises.

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