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Speech Intelligibility in Noise with Single-Microphone Noise Reduction Implemented in 9-, 16-, and 24-Channel Compressors

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Abstract

Reception Threshold for Sentences (RTS) as measured by a modified version of the HINT test [M.J. Nilsson et al., J. Acoust. Soc. Am. 95(2), 1085-1099 (1994)] were collected on hearing-impaired listeners fit binaurally with digital hearing aids incorporating a 9-channel, 16-channel, and 24-channel 'spectral subtraction'-like technique of single-microphone noise reduction. Thresholds were measured in noise presented in a two-dimensionally diffuse soundfield with the subjects listening unaided, aided without noise reduction, and aided with noise reduction. The ability of noise reduction to reduce the level of steady state noise was quantified using 2 cm3 coupler measures with flat linear fittings (to measure the maximum attenuation possible) as well as using each of the listeners' prescribed fittings (to better relate to the changes in performance measured in the sound field). Previously measured benefit from noise reduction [(M.J. Nilsson et al., J. Am Acad. Aud. (2005)] is hypothesized to occur from frequency-specific gain manipulations that increases gain in frequencies where speech is the dominant signal and decreases gain in frequencies where noise is the dominant signal. Additional benefits from smaller, independent channel structures are therefore expected from the 16 and 24 channel systems

INTRODUCTION

Single-microphone noise reduction has a long history of providing theoretical benefit, and limited evidence of measurable performance improvements1,2. The ability to improve signal-to-noise ratio (SNR) is only possible if gain can be independently adjusted across frequency to selectively amplify regions with a positive SNR, and decrease the gain in regions with a negative SNR. Compression channel structures can change the ability to separate positive and negative SNRs. To test this hypothesis, three signal processing algorithms were tested that varied in the frequency bandwidth of the compression channels. If performance improvements are dependent upon adequate frequency resolution, then the system with the finest resolution is more likely to demonstrate benefit.

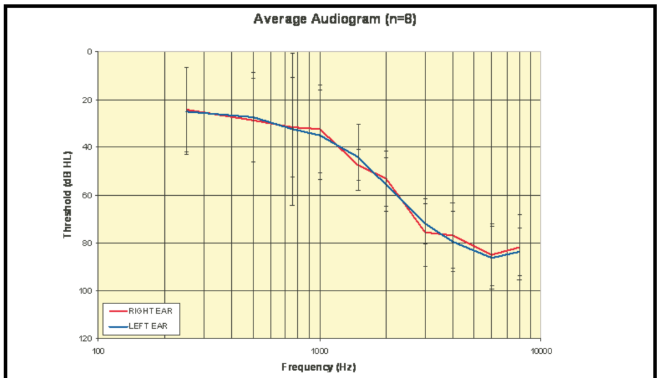

Figure 1: Mean Audiogram

METHOD

Subjects: 8 individuals (6 male; 2 female) with mildly-to steeply-sloping bilateral sensorineural hearing loss. Mean audiograms for the right and left ears are shown in Figure 1. Subjects ranged in age from 62 to 85 years, with a mean age of 74 years.

Devices: Subjects were fit binaurally with 3 different pairs of digital, multi-channel compression, behind-the-ear hearing aids utilizing 9-channel (SONIC innovations Natura2), 16-channel (SONIC innovations Innova), and 24-channel (SONIC innovations Velocity) 'spectral subtraction'-like single-microphone noise reduction (NR). All hearing aids were tested in omnidirectional mode with the NR algorithm either on or off. Each subject wore their own custom earmolds during testing.

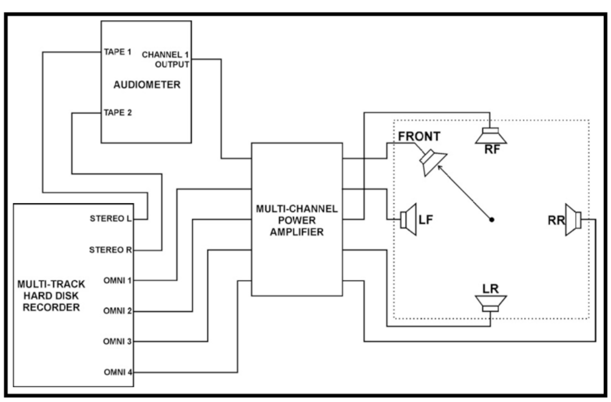

Figure 2: Test Environment

Test Materials: Subjects were tested with the HINT3 using 20 sentence lists and the spectrally-matched steady-state noise designed for the HINT. Presentation was made in the two-dimensionally diffuse free field shown in Figure 2 using four uncorrelated noise tracks4.

Procedure for Coupler Measurements: Target fitting values were determined first for the 24-channel hearing aid using a proprietary fitting algorithm (Best Fit Fast, SONIC innovations) and the subjects' audiograms. Coupler measurements were completed in a FONIX 7000 test box using a composite noise signal at 65 dB SPL with the NR algorithm off and then set to "Maximum". Measurements were then completed on the 9- and 16-channel aids with the NR algorithm off, adjusting the fittings as needed to obtain the closest fit possible to the frequency response of the 24-channel hearing aid. The NR algorithm was engaged and the coupler measurements repeated.

Procedure for HINT Measurements: Subjects were tested unaided in quiet and noise and aided in noise. The noise presentation level in the aided condition was always 65 dB SPL. The order of device testing was pseudo-randomized. The 20-sentence HINT lists were divided, such that half of the list was completed with the NR algorithm engaged, whereas the other half was completed with it off.

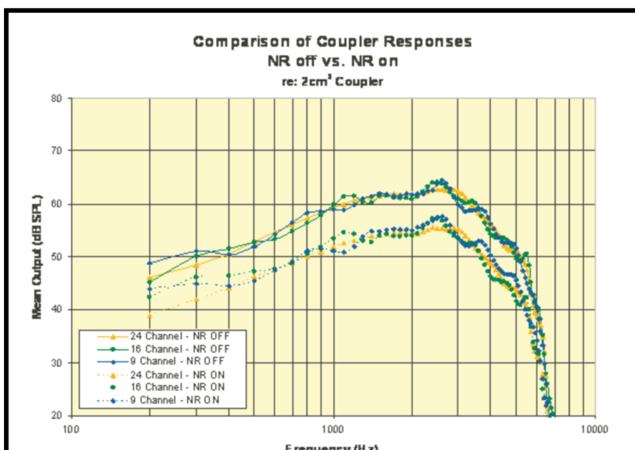

Figure 3: Coupler Measurements

RESULTS

Coupler Measurements: Figure 3 shows the average coupler responses for the sixteen hearing aids with the NR algorithm on (solid lines) and off (dashed lines). When the NR algorithm was off, the average difference between the 24-channel hearing aid and the 16- , and 9-channel hearing aids was only -1.1 and -0.5 dB, respectively. Engaging the NR algorithm reduced the response to the composite noise by an average of 5.5, 6.9, and 6.0 dB for the 9-, 16-, and 24-channel aids, respectively. These closely matched coupler responses suggest that any behavioral performance differences observed in the HINT testing would not be attributable to audibility differences across the three different hearing aids.

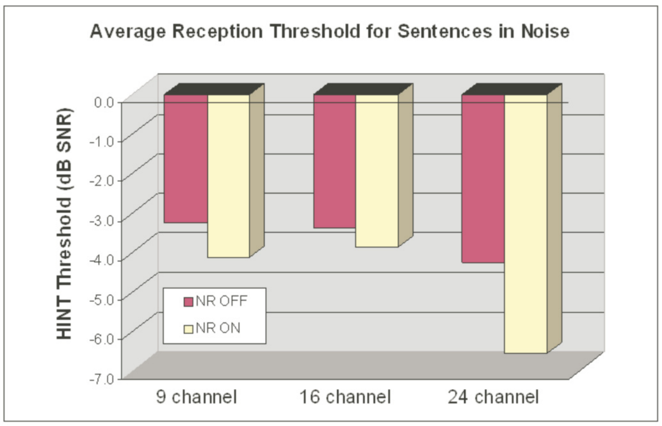

Figure 4: Average HINT Results

HINT Performance: Analysis of Variance was run for the two within-subjects variables: noise reduction on versus off, and compression system. A main effect of device was found [$F(2,14)=7.22$, $p<.01$], with Bonferroni-corrected post-hoc analysis revealing that the 9-channel and 24-channel results were different from each other (-3.69 dB SNR and -5.41 dB SNR, respectively). A main effect of noise reduction was also found [$F(1,7)=5.79$, $p<.05$] with better performance with noise reduction (RTS of -4.85 dB SNR) than without (RTS of -3.63 dB SNR). No significant interaction was found.

CONCLUSIONS

Results demonstrate that even with careful matching between devices to control for audibility, differences can be found based upon the compression structure and design of the system. All three systems applied a similar 'spectral subtraction like' noise reduction, with maximum noise reduction set the same. The noise reduction can be seen to be consistent across frequencies, and a statistically significant improvement in HINT score was demonstrated. The hypothesized increase in noise reduction benefit with increasing number of compression channels was not statistically significant with this small sample, but the mean scores trend in the appropriate direction. These benefits are small compared to the benefits seen with directionality. Previous similar results have been questioned as to clinical relevancy, but as Plomp has said so eloquently, 'every dB counts'.

REFERENCES

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