SPEECH UNDERSTANDING IN NOISE AND INTEREAR COMPRESSION

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INTRODUCTION

Sensorineural hearing loss impacts a listener's ability to understand speech in noise, even in environments where sources of speech and noise are separated from each other by distance (Noble et al 1997). Distortion of frequency and temporal cues, along with reduced audibility, are likely responsible for the observed difficulty with understanding speech in noise (Noble et al 1997; Bronkhorst & Plomp 1989). Use of amplification can create further problems in these environments, even with an increase in audibility of the speech signal (Van den Bogaert et al 2006). This may be related to the reduction of binaural hearing cues, as each hearing aid processes sound separately of one another, and the natural timing and level differences of sounds are lost (Van den Bogaert et al 2006).

Current hearing aids are being developed with the ability to wirelessly share information on a listener's environment. This InterEar (IE) feature is designed to reintroduce the binaural cues typically lost with the use of hearing aids. The current study was designed to examine subject performance on a speech in noise task with and without the use of IE Compression, to determine if the addition of binaural cues had any effect on speech in noise performance.

METHODS

Hearing instrument

- Widex Clear 440 Passion, Receiver in Canal
  - 15 channel
  - Fully adaptive directional microphone
  - Speech intelligibility based noise reduction
  - Multi directional active feedback cancellation
  - Inter ear communication [compression, noise reduction, volume, program]
- Custom CAMISHA shells made for each participant
- Venting based on hearing loss at 500 Hz
- <20 dB = open fit; 20-29 dB = 1.5-2mm; 30-39 dB = 1-1.5mm; 40-49 dB = 0.5-1mm; 50-60 dB = 0-0.5mm

InterEar (IE) Compression

The IE Compression feature is utilized in speech in noise listening environments where incoming sounds are more dominant on one side of the listener's head. IE Compression allows the hearing aids to share information on the input level of sounds from the environment. The hearing aids utilize the higher input level to determine gain settings in both hearing aids. Therefore, the amount of gain in both hearing aids is identical, but the output level differs because the input level also differed. This allows for the preservation of interaural level differences (ILD) that are typically lost with the use of binaural amplification.

Participants

- 19 people recruited for the study.
- Average right and left audiogram shown in Figure 1.
- All native English speakers.
- Ages ranged from 63 to 82 years; average 72 years [stdv 5.7 years]
- 8 males and 11 females
- 13 experienced hearing aid wearers
- 6 no hearing aid experience

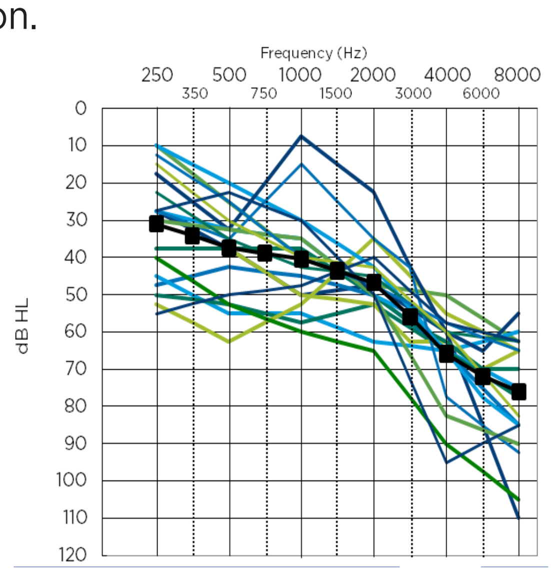

Figure 1: Average right/left audiogram

METHODS [cont.]

Equipment Set up

- Testing was conducted in a double-wall sound-treated booth (Industrial Acoustics), with internal dimensions of 10' x 10' x 6'6".
- Monthly calibration of all test equipment was conducted in each lab, in addition to daily calibration checks of the speakers during the course of the study.
- A GSI-61 clinical audiometer was used to obtain unaided thresholds under TDH-39 supraaural headphones.
- All other testing was performed in the sound field using loudspeakers (KRK ST6).
- The sound booth utilized 12 loudspeakers. Each loudspeaker was separated by 30°, forming a 360° circle around a central point 1 meter away from all loudspeakers. Each loudspeaker utilized its own channel.
- To present 12 channels of audio automatically, EchoAudio 12-channel firewire audio interface (AudioFire12) was used. A 12-channel power amplifier (Niles SI1230) was used to drive the loudspeakers.
- Only speakers at 90⁰ and 270⁰ were used for this data collection.

Test Stimulus

Widex Office of Research in Clinical Amplification Nonsense Syllable Test (ORCA NST):

- The ORCA NST consists of 32 nonsense words created in the CVCVC format.
- 25 consonants found in American English (p, t, k, b, d, g, m, n, ŋ, f, v, θ, ð, s, z, ʃ, ʒ, l, w, ʍ, ɹ, j, h, tʃ, dʒ) and five vowels found in American English (i, ^, æ, ɑ, u) were used to create the nonsense words.
- The nonsense words were presented to the subject in a randomized order.
- The female version of the test was utilized.
- A carrier phrase was presented to the subject, followed by the nonsense word.
- The subject was instructed to repeat the nonsense word exactly as they heard it, even if they were only able to hear part of the item.
- A custom computer program was used to present the speech stimuli and the speech-weighted noise and to allow the test giver to score the subject's responses.
- Percent correct scores are derived from the correct identification of consonants in each 32-item list.

Test Procedure

- The ORCA NST was presented from the 270º speaker and speech-weighted HINT noise was presented from the 90º speaker.
- The separation of speech and noise signals was intended to activate the IE Compression feature, which is designed to operate when speech is dominant on one side of the head.
- The speech was presented at 68 dB SPL with varying SNR levels.
- One list of the ORCA NST was completed at each SNR from -10 dB SNR to +10 dB SNR, with step sizes of 5 dB.
- One list of the test was also performed in quiet. This allowed a performance intensity (PI) function to be created.
- The hearing aids were in the IE Compression Off setting.
- The PI function was utilized to determine a subject's two SNR levels that best represented the subject's most sensitive performance point.
- These two SNR levels were retested with IE Compression On.

RESULTS

ORCA NST: -5 dB SNR and 0 dB SNR

Figure 2 displays the average percent correct scores for the two conditions, both in IE Off and IE On. The subjects performed better in IE On than IE Off in the two conditions. The majority of subjects demonstrated 50% correct performance at -5 dB SNR and 0 dB SNR, so statistics on IE benefit is focused on these two noise conditions. Note that the number of subjects in each noise condition is different, because not all subjects had the most sensitive performance at the same SNR.

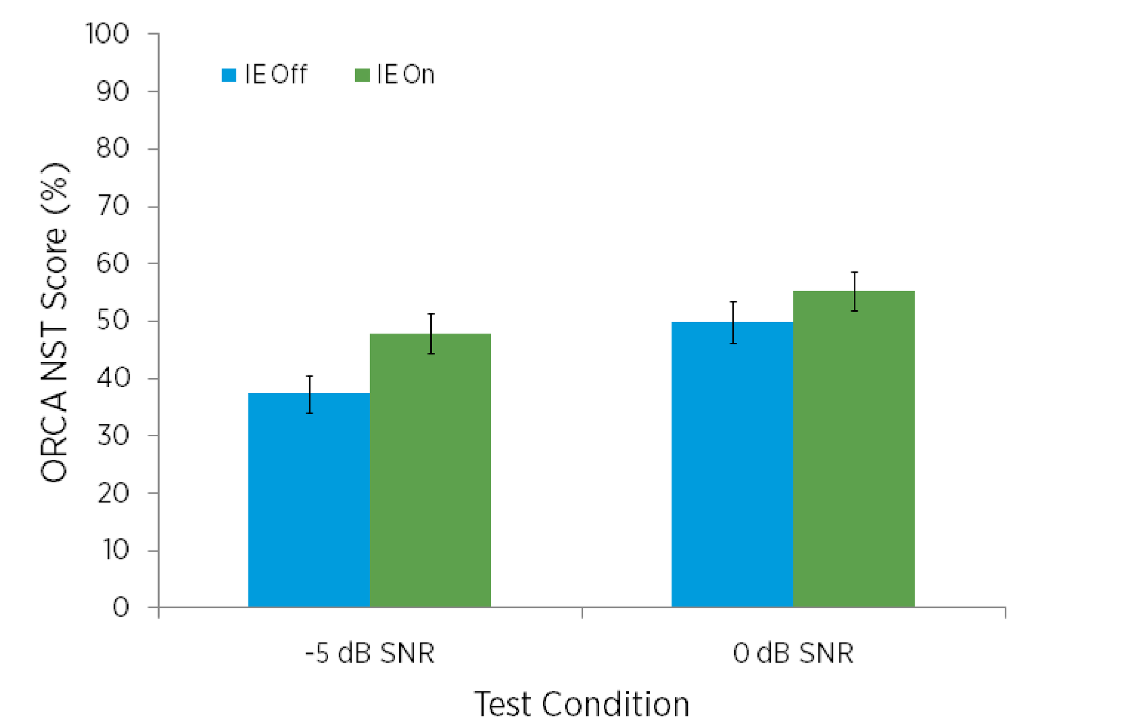

Figure 2: ORCA NST test scores obtained in the two test conditions with IE On and Off. Error bars denote standard error about the mean.

Table 1 shows the mean difference in consonant scores between IE On and IE Off for the test conditions of -5 dB SNR and 0 dB SNR. Results show that IE On performance is significantly better than IE Off performance in both test conditions ($p<0.05$).

Table 1: Inferential t-test examining the mean difference of consonant scores between IE On and IE Off with -5 dB SNR, and 0 dB SNR performance conditions.

test condition	Mean difference (%)	Std dev of difference (%)	N	t	p
0 dB SNR	5.3	5.3	15	3.88	0.002
-5 dB SNR	10.4	5.6	16	7.38	0.000

ORCA NST: Frequency Content

The consonants on the ORCA NST were classified into low-, mid-, and high-frequency content groups, based on the average location of the first spectral peak of each consonant. The percent correct scores on the ORCA NST were measured for each consonant group in the IE Off and IE On conditions.

Table 2: Classification of ORCA NST consonants based on averaged peak spectral energy.

Below 2 kHz	Between 2-4 kHz	Above 4 kHz
l	m	f
r	n	h
w	ŋ	s
	ʍ	z
	ʃ	θ
	ʒ	ð
	tʃ	t
	dʒ	d
	k	v
	g	p
	b	
	j	

All analysis in this section was done at -5 dB SNR, as this SNR proved to be the most sensitive noise condition for the majority of subjects. The consonant classifications are shown in Table 2. Note that there are differing numbers of consonants in each group.

RESULTS [cont.]

Figure 3 displays average scores based on the frequency content of the consonants. An improvement in performance with IE On versus IE Off was observed for all three frequency content groups. Statistical analysis revealed IE condition to be significant ($F(1, 15) = 54.83$, $p < 0.001$, $\eta^2 = 0.78$) and frequency content to be significant ($F(2, 30) = 65.45$, $p < 0.001$, $\eta^2 = 0.81$). The interaction between IE condition and frequency content was also significant ($F(2, 30) = 5.08$, $p = 0.013$, $\eta^2 = 0.25$). Post-hoc analysis with Bonferroni adjustment for multiple comparisons revealed only the low- and mid-frequency groups had significantly different performance between IE conditions ($p< 0.05$).

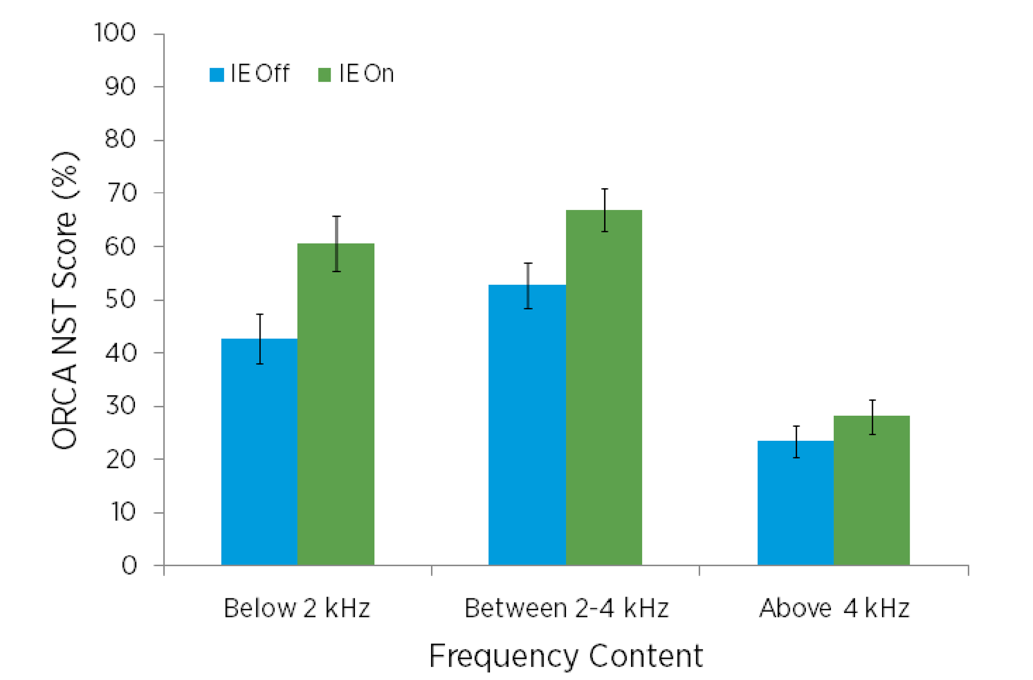

Figure 3: ORCA NST test scores based on frequency content of consonants with IE On and off. Error bars denote standard error about the mean.

CONCLUSIONS

IE Compression is a wireless feature designed to restore binaural cues typically lost with the use of fast acting WDRC hearing aids. The current study was designed to examine the effects of IE Compression on a speech understanding in noise task. Results demonstrate that use of IE Compression led to significant improvements in average subject consonant identification at differing SNR levels, including individual SNR where greatest IE benefit was observed for each subject. Significant improvements in performance with IE On were noted for low- and mid-frequency consonants. No significant improvement was observed for high-frequency consonants, however. These results indicate that the use of IE Compression may allow for better speech understanding in noise in situations where speech and noise originate from opposite sides of the listener's head.

REFERENCES

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