AMPLIFICATION IN NOISE FOR LISTENERS WITH SEVERE TO PROFOUND HEARING LOSS

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INTRODUCTION

The use of directional microphones and digital noise reduction (DNR) was once limited in the severe to profound hearing loss (SPHL) population, because an unwanted reduction of overall loudness could occur[1]. Advances in digital signal processing technology[2,3] could reduce the loss of loudness from use of these features. The current study measured the efficacy of directional microphones and DNR utilizing the technology outlined below in a group of participants with SPHL.

Directional microphones

Fifteen-channel, fully adaptive directional microphones were utilized in the current study[2]. Speech understanding benefit from use of fixed, single-channel directional microphones has been observed in SPHL listeners[4,5] but the multichannel, fully adaptive nature of current microphones provides some possible advantages for the SPHL over fixed/single-channel directionality.

- The multichannel feature of the hearing aid allows for each channel to utilize any polar pattern from omnidirectional to bi-directional. An advantage for SPHL listeners is that low frequency channels remain in omnidirectional mode until loud low frequency input is detected. This prevents the need for gain compensation and leaves more headroom for increases in low frequency gain.
- Directional microphones are not activated until the sound source exceeds 55 dB SPL[2]. This prevents the directional microphones from becoming activated in quieter situations, when reduced loudness may prevent audibility for a SPHL listener.
- The activation time from an omnidirectional mode to bi-directional mode may take as long as 10 seconds[2]. This gives the listener time to assess the environment and optimize orientation towards a desired sound source before any unwanted decrease in loudness from the directional microphones occurs.

Digital noise reduction (DNR)

Two DNR algorithms were evaluated in the current study- a traditional DNR and a "speech enhancing" DNR algorithm (Widex Speech Enhancer)[3]. The Speech Enhancer (SE DNR) could minimize loss of audibility for SPHL listeners in the following ways:

- The traditional DNR algorithm does not consider the degree of hearing loss of the user when calculating gain reduction[3]. On the other hand, SE DNR does consider the listener's hearing thresholds. For a SPHL listener, SE DNR will prescribe less gain reduction in noise in order to prevent loss of audibility.
- SE DNR uses the Speech Intelligibility Index (SII) to calculate gain settings for optimized speech intelligibility in noise[3]. Based on the SII measurements, gain reduction is applied, but increases in gain can also occur (up to 5 dB per channel), if doing so would be advantageous to speech audibility without causing discomfort. For a listener with SPHL, this type of noise reduction may provide gain reduction in noise without sacrificing audibility.

METHODS

Study particpants

8 listeners with SPHL participated in the study. They are described as follows:

- 6 females, 2 males
- Average age = 50 years (standard deviation [SD] = 15.1 years)
- Average three frequency pure tone average (0.5, 1, 2 kHz):
  - o Right ear = 87 dB HL (SD = 15.7dB HL)
  - o Left ear = 84 dB HL (SD = 14.8 dB HL)
- Average experience with hearing aids = 35 years (SD = 14.1 years)

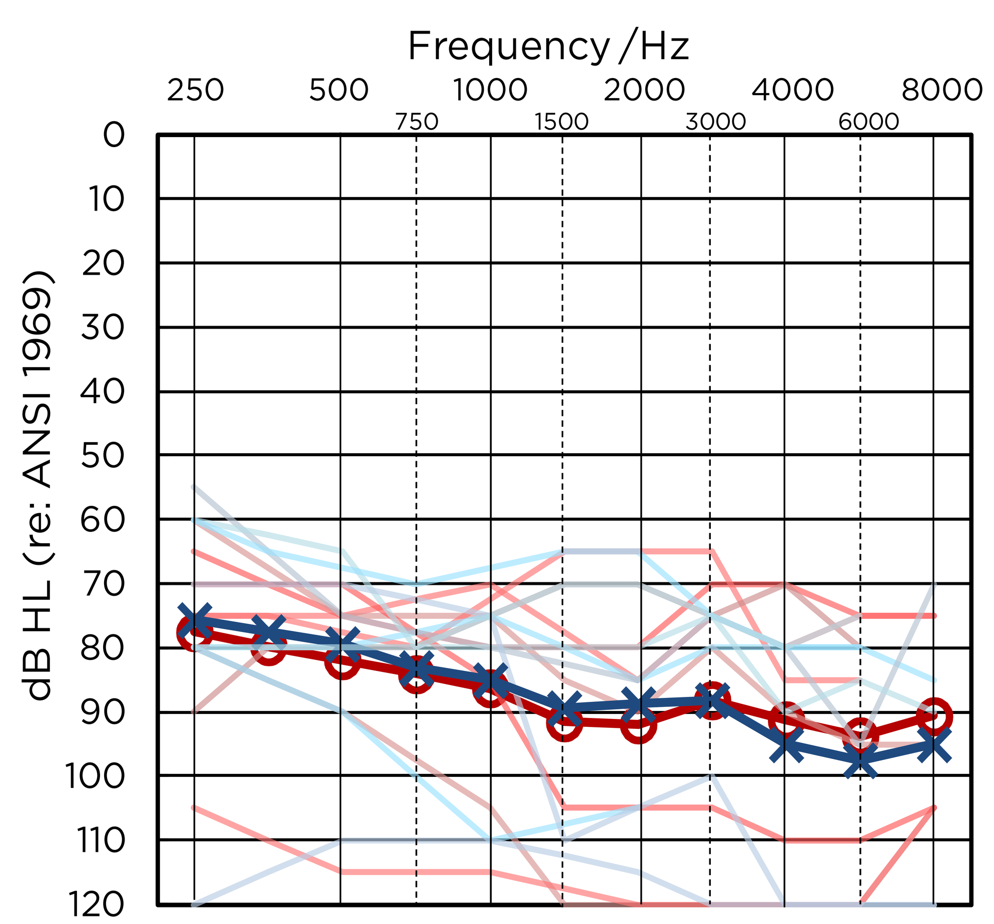

Figure 1: Air conduction thresholds of participants included in the analysis (n=8). Bold lines indicate average thresholds for the right and left ears.

Test procedure

Participants were fitted binaurally with super power receiver in the ear (RITE) hearing aids (Widex Super 440) and custom full-size shells. The participants completed testing immediately following the hearing aid fitting. Speech understanding in noise was measured using the Connected Speech Test (CST)[6] in an auditory only mode. The CST was completed at an individualized signal to noise ratio (SNR), which predicted approximately 50% performance. In order to determine maximum performance for each participant, the CST was performed aided in quiet.

Subjective tolerance for speech in noise was measured using the Acceptable Noise Level (ANL) test[7]. Testing was completed in a sound booth, with speech originating from 30° azimuth and steady-state speech-weighted noise originating from 210° azimuth. The participants were tested in a counterbalanced manner for both tests in six total listening conditions:

Omnidirectional mode	Directional mode
o No DNR	o No DNR
o Traditional DNR	o Traditional DNR
o SE DNR	o SE DNR

RESULTS

Speech understanding in noise

Five of eight study participants were able to complete the CST in noise. Test results for these participants are displayed in Figure 2.

- The difference in average CST score from omnidirectional to directional:
  - o + 31.6% in no NR
  - o + 29.2% in traditional NR
  - o + 35.2% in SE NR

The difference in average CST score from no NR to NR:
  - o + 2% in omni mode (trad. NR)
  - o + 0% in omni mode (SE NR)
  - o -0.4% in dir mode (trad. NR)
  - o + 3.6% in dir mode (SE NR)
- Directional mode improved speech in noise performance equal to aided performance in quiet. An average score of 68% was measured for the CST in quiet (omni, no DNR), while the average directional microphone performance (for all DNR conditions) was 73%.

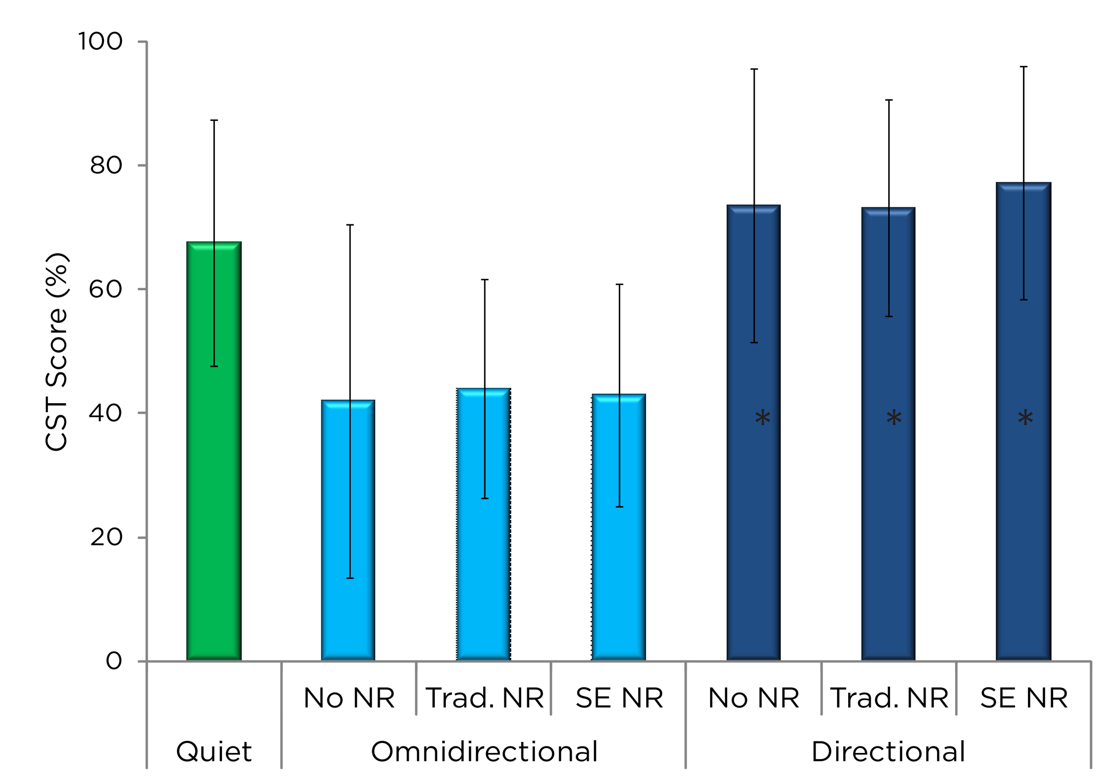

Figure 2: Average CST score (%) for six microphone/DNR conditions at the fitting (n=5). Note quiet condition = omnidirectional mic, no DNR. Error bars denote +/- 1 SD about the mean. * = statistical difference between microphone conditions.

- Two-factor repeated measures analysis of variance (RMANOVA) (microphone, DNR) revealed:
  - o Microphone: Significant difference in CST score was measured ($p < 0.05$) Post hoc analysis revealed better performance in directional mode over omnidirectional mode.
  - o DNR: No significant difference in CST score was measured ($p > 0.05$). Traditional DNR and SE DNR did not improve CST score in noise; however, neither DNR algorithm negatively affected CST score.
  - o No significant interactions between microphone and DNR.

Subjective noise tolerance

ANL test results for all 8 participants are displayed in Figure 3. Note that a negative change in SNR suggests greater tolerance to noise.

- The difference in average ANL score from omnidirectional to directional:
  - o - 11.9 dB in no NR
  - o - 9 dB in traditional NR
  - o - 10.5 dB in SE NR

RESULTS [cont.]

The difference in average ANL score from no NR to NR:
  - o -4.5 dB in omni mode (trad. NR)
  - o -0.9 dB in omni mode (SE NR)
  - o +1.6 dB in dir mode (trad. NR)
  - o -0.5 dB in dir mode (SE NR)
- Two-way repeated measures ANOVA (microphone, DNR) revealed:
  - o Microphone: Significant difference in ANL score ($p < 0.05$). Post hoc analysis revealed improved noise tolerance in directional mode over omnidirectional mode.
  - o DNR: Significant difference in ANL score ($p < 0.05$). Post hoc analysis revealed improved noise tolerance with traditional DNR over DNR off.
  - o No significant interactions between microphone and DNR.

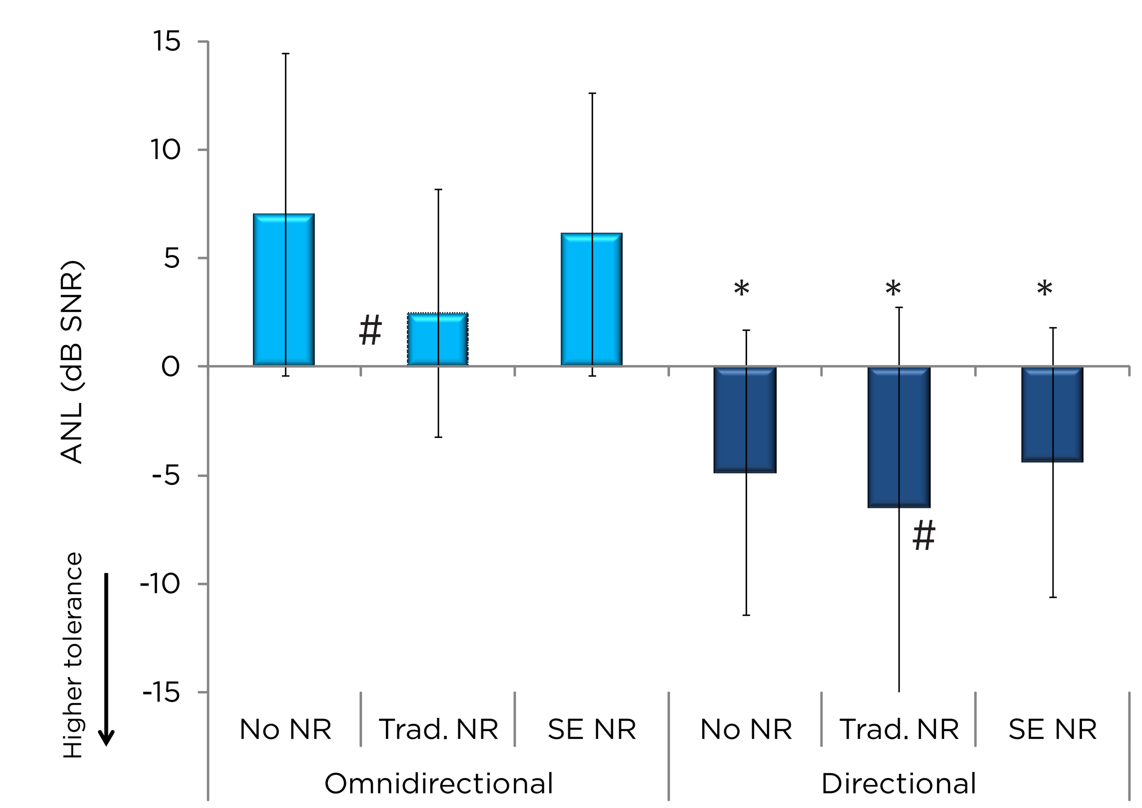

Figure 3: Average ANL score (dB SNR) for six microphone/DNR conditions at the fitting (n=8). Error bars denote +/- 1 SD about the mean. * = statistical difference between microphone conditions; # = statistical difference between DNR conditions.

CONCLUSIONS

The SPHL listeners in the current study received benefit from use of multichannel, fully adaptive directional microphones during testing, as greater speech testing accuracy and comfort in noise were observed in the directional mode over omnidirectional. Measureable effects from use of SE DNR were not observed, though traditional DNR appeared to provide greater comfort in noise (as the algorithm likely provided more gain reduction than SE DNR, due to the severe nature of the subjects' hearing losses). The benefits observed in the current study were measured immediately at the fitting.

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