

## ABSTRACT

Reports indicate that the unaided acceptable noise level (ANL) is correlated with hearing aid success and that aided ANL scores may be reduced by digital noise reduction (DNR) when measured using sentences in continuous speech-shaped noise. Here, ANL scores were obtained using read speech and multi-talker babble for 36 subjects with sensorineural hearing loss. Aided ANLs were significantly lower with DNR and increased with speech level for subjects with mid and high ANLs but not for subjects with low ANLs.

## INTRODUCTION

Willingness to accept hearing aids relates to willingness to accept or tolerate background noise in the presence of conversational speech - Acceptable Noise Level (ANL)

It is possible that overall hearing aid satisfaction (and use) will increase if hearing aid technology can enhance comfort and quality and reduce fatigue in noisy environments

Digital Noise Reduction (DNR) may lead to lower (better) ANL scores, indicating greater acceptance of noise, and by deduction, improve hearing instrument satisfaction and use

### Characteristics of the ANL

- Not correlated with SPIN scores<sup>8</sup>
- Not related to type of hearing aid<sup>2</sup>, age<sup>7,9</sup> or degree of hearing loss<sup>4,9</sup> (unaided ANLs)
- Gender difference: No<sup>9,13</sup>; Females prefer less noise<sup>5</sup>
- Similar in unaided and aided conditions<sup>8</sup>
- Increases with increasing speech presentation level in normally hearing Ss<sup>1</sup>
- Stable over time (3 month period)<sup>8</sup>
- Is repeatable/reliable? Yes<sup>3</sup>, No<sup>10,11</sup>

### Purpose of Study

- To determine the effect of DNR on aided ANL measures in multi-talker babble
- To determine the effect of stimulus presentation level on aided ANL measures
- To establish within session intrasubject repeatability (test re-test) using fixed presentation level procedures

## METHODS

### Participants

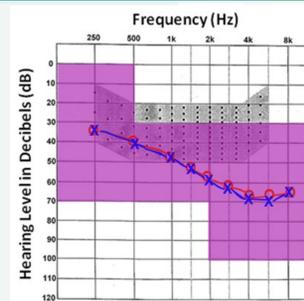
- 36 subjects (mean age = 67 years), mild to moderately-severe, symmetrical, sensorineural hearing loss

### Cohorts (Nabelek et al. (2006))

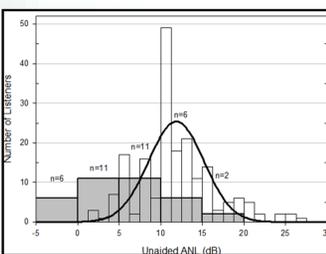
- Low ANL (< 7.0 dB): n=19 unaided, n=12 aided
- Mid ANL (7.1 to 13.0 dB): n=12 unaided, n = 13 aided
- High ANL (> 13.0 dB): n=5 unaided, n = 11 aided

### Procedures

- Automated testing
  - Instructions, stimulus timing, response collection, stimulus level under automated MATLAB GUI control
  - Auditory and visual instruction slides match GUI
- Unaided ANL at speech presentation level of 65 dBA
  - Arizona Travelogue, 12-talker babble, 0° azimuth
- Starkey X Series RIC, custom earmold
  - NAL-NL2, ±3 dB, real ear (Verifit) speech mapping
  - Advanced signal processing features disabled
  - Voice IQ<sup>2</sup> DNR algorithm at most aggressive setting
- Aided ANL Conditions
  - 3 fixed speech presentation levels: 50, 65, and 80 dBA
  - 2 DNR settings: DNR on (maximum setting); DNR off
  - 3 ANL repetitions per unaided and aided condition
  - 18 total aided conditions counter balanced



**Figure 1.** Pure tone criteria and mean thresholds (symbols)

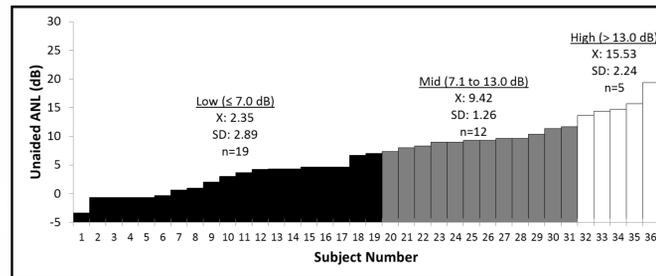


**Figure 2.** Distribution of ANL scores for this study (shaded boxes) and Nabelek et al.<sup>9</sup> (narrow bars)

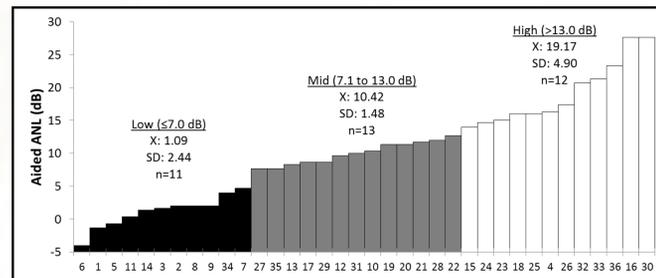
## RESULTS

### Unaided versus Aided ANL Scores

**Figure 3.** Upper Panel: Unaided ANL (speech presentation level = 65 dBA) ordered from low to high for 36 subjects. Shading indicates low, mid, and high ANL cohorts using Nabelek et al. criteria<sup>9</sup>. Distribution of subjects was uneven despite testing many subjects

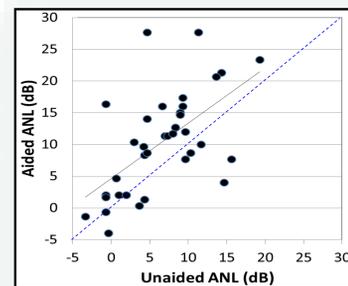


Lower Panel: Aided ANL (speech presentation level = 65 dBA) ordered from low to high for 36 subjects. Subject numbers on the x axis match the upper panel.



**Figure 4.** Unaided vs. Aided ANLs. Moderate correlation between unaided and aided ANLs ( $r = 0.59$ ;  $r^2 = 0.35$ )

- Unaided ANLs were significantly lower than aided ANLs ( $t_{35} = -3.514$ ,  $p = 0.001$ )
- Unaided ANLs ranged from 3.3 to 19.3 dB (mean: 6.6 dB; SD: 5.4 dB)
- Aided ANLs ranged from -4.0 dB to 27.7 dB (mean: 10.3 dB; SD: 8.0 dB)



### ANL as a Function of Presentation Level and DNR

**Figure 5.** Aided ANL vs. input speech level across DNR off (shaded) and DNR on (open) conditions for the High (upper) Mid (middle) and Low (panel) ANL cohorts based on Nabelek et al. criteria<sup>9</sup>.

### Aided ANL Increases with Input Speech Level

RMANOVA ( $p < 0.001$ ) and post-hoc testing:

- ANL values were significantly different across cohort (largest for High and smallest for Low)
- ANLs increased with increasing input speech level (significant change with level for the Mid and High but not Low cohorts)

### ANL Decreases with DNR

RMANOVA ( $p < 0.001$ ) and post-hoc testing:

- ANL was significantly lower with DNR engaged than with DNR off
- Across the three speech presentation levels and three cohorts, ANL decreased an average of 2.1 dB with DNR engaged versus DNR off.

### ANL and Other Subject Characteristics

Neither unaided or aided ANL scores were correlated with age, gender, hearing aid ownership, hearing aid use (full time, part time, minimal), pure-tone average, Word in Noise (WIN) test, or tinnitus.

## RESULTS CONTINUED...

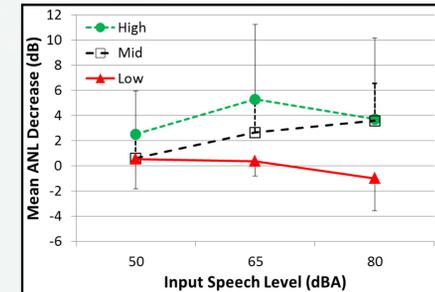
### DNR Benefit

**Figure 6.** Change in ANL (ANL with DNR On minus ANL with DNR off) as a function of input speech level averaged across subjects (bars = indicate 1 standard deviation)

ANL decreased 3.9 dB for the High cohort, 2.3 dB for the mid cohort, and 0.0 dB for the low cohort.

### ANL test re-test repeatability

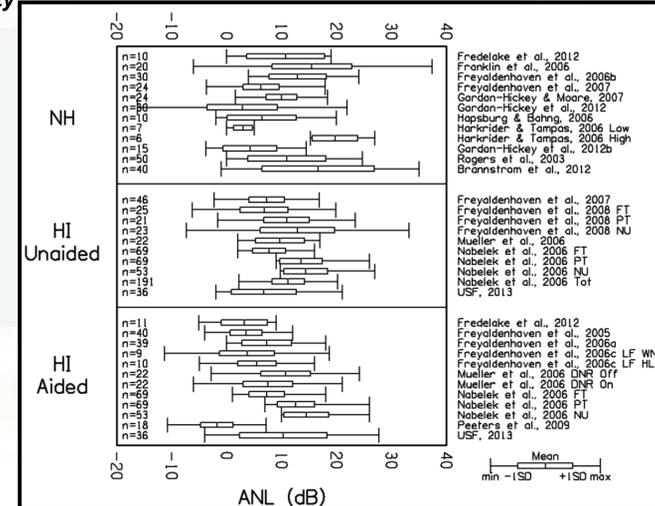
- Interclass correlation coefficient (ICC)
- Unaided ICC = 0.998; Median intrasubject SD 1.15 (0 to 5.5 dB)
- Aided ICC = 0.997; Median intrasubject SD 1.52 (0 to 9.0 dB)
- Very High Repeatability**



$$ICC = \frac{MS_b - MS_w}{MS_b + (k - 1)MS_w}$$

### Figure 7. ANL summary

Upper: normal hearing; Middle: hearing impaired unaided, Lower: hearing impaired aided. Authors, year, subject descriptor (right) number (left) are given. **Descriptors.** Low: low ANL group; High: high ANL group; FT: Full time HA users; PT: Part time HA users; NU: non HA users; Tot: All subjects; LF WNL: normal low-frequency hearing; LF HL: low-frequency hearing loss; DNR Off; DNR On.



## CONCLUSIONS

- Aided ANL scores increase with increasing speech presentation level for the High and Mid but not the Low cohort
- ANL is significantly lower with DNR engaged for the High and Mid but not the Low cohort
- ANL has very high intrasubject repeatability
- ANL scores vary widely across subjects
- Speculation: ANL task decision criteria may be "loudness" based for some subjects (e.g., Mid and High cohorts; level and DNR dependent) and "intelligibility based for other subjects (e.g., Low cohort; independent of level and DNR).<sup>12</sup>

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### Acknowledgements

Work supported by Starkey Hearing Technologies; USF Global Center for Hearing & Speech Research.