TIME SERIES ANALYSIS OF HINT DATA WITH AND WITHOUT DIGITAL NOISE REDUCTION

Jenn Schumacher, AuD
Widex Office of Research in Clinical Amplification, Lisle, IL

INTRODUCTION

The following poster describes an item-by-item analysis of Hearing In Noise Test (HINT) data measured with and without digital noise reduction (DNR) over multiple studies. The HINT estimates the signal to noise ratio (SNR) necessary for 50% correct identification of speech presented in noise[1]. Twenty-one sentences are presented in noise and the listener is asked to repeat each sentence. The SNR changes across each item based on the listener's previous response. The final score is expressed in a single SNR, which reflects an average of the SNRs from sentences 6-21.

Previous studies have reported no significant difference in final HINT score between DNR on and DNR off[2,3]. However, these studies have examined traditional DNR algorithms with no DNR only. In the current analysis, two types of DNR algorithms were evaluated- a traditional DNR algorithm and a "speech enhancing" algorithm known as the Widex Speech Enhancer (SE DNR)[4]. SE DNR uses the Speech Intelligibility Index (SII) to calculate gain settings to optimize speech intelligibility in noise while still providing comfort. An investigation on SE DNR has shown an average 2.5 dB advantage over no DNR as measured by the HINT[5].

None of the previous studies reported HINT data regarding individual items on the test. It is possible that differences in signal processing across DNR conditions may result in more visible speech in noise performance differences at various points in time, even if final scores suggest no difference. An item-by-item analysis across each test item on the HINT was performed, in order to gain more information regarding speech in noise abilities across time with and without DNR.

METHODS

Study participants

A total of 51 listeners from three past studies conducted at Widex ORCA-USA were included in the current analysis. The participants are described as follows:

- Average age = 68 years (standard deviation [SD] = 12.1 years)
- 30 males, 21 females
- Average three frequency pure tone average (0.5, 1, 2 kHz):
  - Right ear = 45.0 dB HL
  - Left ear = 45.2 dB HL
- Average experience with hearing aids = 18 years (SD = 14.1 years)

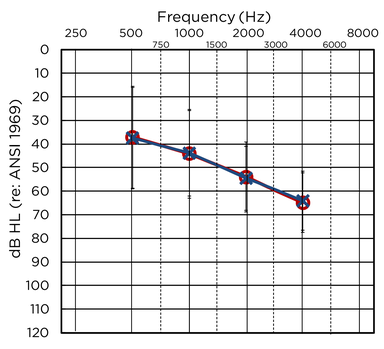

Figure 1: Air conduction thresholds from 500-4000 Hz of all participants included in the analysis (n=51). Error bars denote +/- 1 SD about the mean.

METHODS [cont.]

Studies included in current analysis

In order to be included in the retrospective analysis, all studies had to include:

- Participants with mild to severe hearing loss fitted binaurally with hearing aids
  - Various hearing aid models were utilized but all models employed omnidirectional microphones, traditional DNR and SE DNR.
- HINT data collected in three DNR conditions (off, traditional, SE)
  - Starting speech/noise level (75-76 dB SPL at 0 dB SNR)
  - Continuous speech-shaped noise (filtered to match the test speaker)

Study 1[5]
Examined the efficacy of DNR for speech understanding and comfort in noise.

- 20 participants
- Speech signal = 0° azimuth, noise signal = 90°, 180°, 270° azimuth
- Widex Inteo open fit BTE, Inteo ITC
- Reported 2.5 dB improvement in final HINT score with use of SE DNR over no DNR.

Study 2[6]
Examined the effect of maximum power output (MPO) settings on speech understanding in noise abilities with DNR.

- 19 participants
- Speech signal = 0° azimuth, noise signal = 0° azimuth
- Widex mind 440 BTE
- Reported poorer HINT scores with low MPO setting. DNR improved HINT scores over no DNR in low MPO setting.

Study 3
Measured HINT performance with DNR and correlation with performance on digit span task.

- Speech signal = 0° azimuth, noise signal = 0° azimuth
- Widex Clear 440 micro BTE
- A weak correlation was measured between HINT and digit span in SE DNR.

Test procedure

A customized computer program version of the HINT (written in Visual Basic) was utilized for testing in all three studies. The program stores the speech level, noise level and a correct/incorrect participant response for every item on the HINT. This information is automatically saved and written into a .txt file at the conclusion of the test list.

For the current analysis, speech and noise level were extracted from the .txt files and converted to SNR. The SNRs were averaged across all participants in the three studies for all HINT items, including final score.

RESULTS

Overall average results

HINT scores (in dB SNR) are averaged for the three DNR conditions and displayed in Figure 2.

- Beginning at item 3, the lowest average SNRs were measured in SE DNR and the highest SNRs were measured with DNR off. Performance in traditional DNR fluctuated throughout the test.
- Two-tailed t-test revealed significant differences between the DNR conditions ($p < 0.017$):
  - SE and No DNR: items 3-20, final
  - Traditional DNR and No DNR: items 4, 13-18, final score
  - SE and traditional DNR: items 5-6

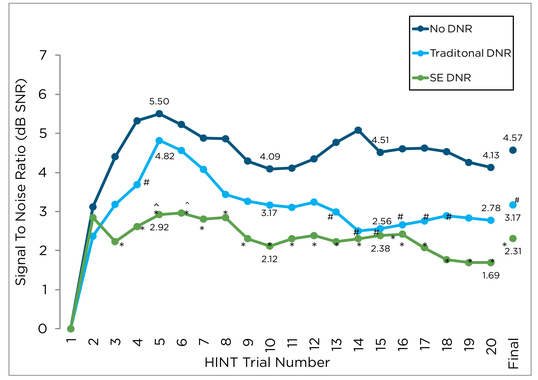

Figure 2: HINT score (dB SNR) for each item from all studies in three DNR conditions. * = SE is significantly better than No NR; # = traditional DNR is significantly better than No NR; ^ = SE is significantly better than traditional DNR.

Table 1 illustrates how performance in traditional DNR changed across items.

- At item 5, traditional DNR performance was 0.68 dB better than DNR off, while by item 15, the improvement over DNR off increased to 1.95 dB. SE DNR showed a 1.90 dB improvement over traditional DNR at item 5, while the SE DNR advantage had decreased to 0.18 dB by item 15. The final score suggests performance in traditional DNR falls between DNR off and SE DNR performance, with a significant difference from DNR off. The final score does not reflect the initial similarity between traditional DNR and DNR off.

	Item 5	Item 10	Item 15	Item 20	Final (Items 6-21)
DNR off- traditional DNR	0.68 dB	0.92 dB	1.95 dB*	1.35 dB	1.40 dB*
Traditional DNR- SE DNR	1.90 dB*	1.05 dB	0.18 dB	1.09 dB	0.86 dB

Table 1: Average difference in scores (dB SNR) for each DNR condition. Positive scores indicate improved performance across time, while negative scores indicate worsening performance. * = significant difference (measured with two-tailed t-test, $p < 0.017$) between conditions.

RESULTS [cont.]

Table 2 illustrates the difference in performance across time within each DNR condition.

- Two-tailed t-test revealed a significant difference between performance at items 5 and 10 and between item 5 and final score for traditional DNR and DNR off ($p < 0.05$). SE DNR also showed a change in SNR from items 5 to 10 and item 5 to final score. The difference between item 5 and item 10 barely reached signficance ($p = 0.05$) but the change from item 5 to final score was not signficant ($p > 0.05$).

	Item 5- Item 10	Item 5- Final
DNR off	1.41 dB*	0.93 dB*
Traditional DNR	1.65 dB*	1.65 dB*
SE DNR	0.80 dB *	0.61 dB

Table 2: Average difference in scores (dB SNR) for each DNR condition. Positive scores indicate improved performance across time, while negative scores indicate worsening performance. * = significant difference (measured with two-tailed t-test) between test items in the DNR condition.

CONCLUSIONS

- In the current analysis, SE DNR demonstrated an advantage over traditional DNR and DNR off in two ways:
  - In SE DNR, the HINT was performed at significantly lower SNRs from item 3 to the end of the test (compared to DNR off). It took until item 13 for traditional DNR to demonstrate consistent difference from DNR off.
  - In SE DNR, listeners required less than a 3 dB increase in SNR before performance stabilized by item 3 of the test. At this time, no more than 1.2 dB of change in SNR was observed by the end of the test. In contrast, traditional DNR and DNR off required a 5-6 dB increase in SNR before performance could improve and stabilize. The need for a higher SNR could cause a listener to miss out on the beginning of a conversation, or require the speaker to increase speech volume in order to be understood.
- It is possible that the SE DNR algorithm processed speech and noise in a way that made it easier for listeners to pick up speech more quickly and at a lower SNR. In a noisy environment, this advantage could allow listeners to follow speech in noise at the initiation of a conversation, preventing the listener from trying to "catch up" with what is being said, and falling further behind in the conversation.
- A signficant difference between traditional DNR and SE DNR was observed only at items 5-6. In the current analysis, participants were directing their full attention to the speech in noise task. It is possible that more difference between the two DNR algorithms could be revealed if full attention could no longer be devoted to the speech in noise task.

REFERENCES

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