The potential for using Hagerman's phase-inversion technique with individual fittings

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Introduction

- The influence of signal-to-noise ratio (SNR) on speech perception and brain activation has been well documented in listeners with normal and impaired hearing [e.g.,1,2].
- One possible reason for the high amount of dissatisfaction with hearing aids (HAs) may be the modification of the SNR delivered to the HA user.
- A technique described by Hagerman and Olofsson [3] permits the measurement of acoustic changes to speech and noise signals at the output of a HA.
- Previous work has shown that the long-term averaged SNR is modified by compression processing [4,5] and some noise reduction algorithms [3], using a limited range of algorithms and fittings.
- Our aim was to extend previous results by using individual fittings, more algorithms, and short-term SNR calculations.

<u>The objectives of this study</u>:

- To investigate the amount of short-term SNR change made by some HA algorithms in individualized fittings.
- To determine the extent of error generated from the Hagerman inversion technique with the selected algorithms and fittings.

Method

- Twenty five subjects with sensorineural hearing loss no worse than 75 dB HL in one ear were recruited (mean age 67.5 yrs., range: 23-87 yrs.; Figure 1).
- Three HAs from three different manufacturers were programmed to match NAL-NL1 real ear targets for a 65 dB SPL digital speech signal.
- Sound field recordings were made in a sound-treated booth on KEMAR (Figure 2).
- Stimuli: presented from 0° azimuth, 1.5 meters from test ear.
  - <u>Speech</u>: CST sentences – fixed level of 65 dB SPL
  - <u>Noise</u>: CST 6-talker babble – set at approximately the listener's SNR-50 (57-65 dB SPL, or 0-8 dB SNR)

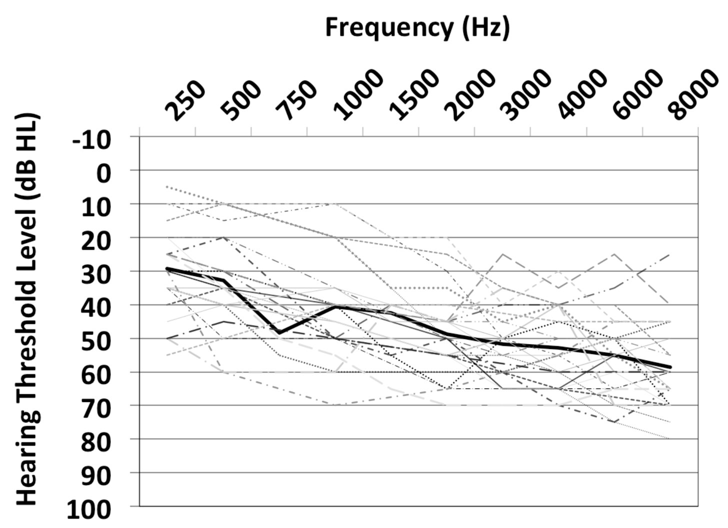


Figure 1. Mean (dark line) and individual (light lines) hearing threshold levels for 25 subjects.

- The aids were tested in four processing conditions: Linear (LIN), Linear + Noise Reduction (LIN + NR), Compression (WDRC), and WDRC + NR.
- The speech and noise signals at the output of the aid were extracted by adding recordings 1 and 2 (extracted speech) and recordings 1 and 3 (extracted noise), shown in Figure 2 using Hagerman's phase-inversion method[3].
- Two RMS levels were measured from the extracted speech and noise signals: the average of the levels obtained in 30 and 120 ms window lengths, over 30 seconds of "test" time.
- The error from using the Hagerman inversion technique with the algorithms used in this study was quantified for every condition and subject by examining the amount of residual sound remaining after combining fully inverted signal recordings (recordings 1 and 4 in Figure 2). The error from combining the fully inverted recordings was subtracted from the speech and noise output levels to estimate the amount of attenuation[6] possible.

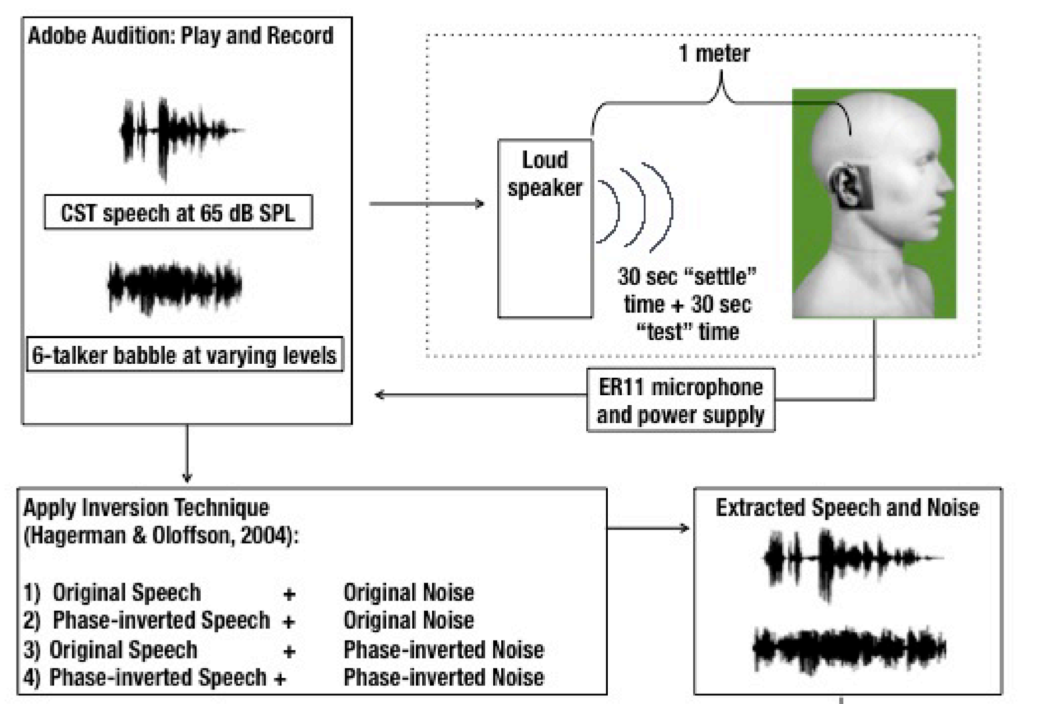
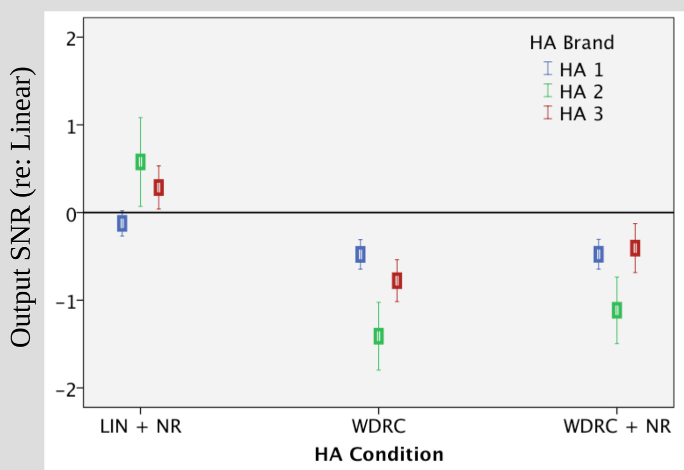


Figure 2. Set up for hearing aid recordings using Hagerman's phase inversion technique.

Results

Figure 3. Mean change in SNR (re: linear) across subjects for each condition using 30ms window lengths. An ANOVA indicated a significant interaction between HA brand and condition, and all main terms were significant (p<0.001). Post-hoc testing with corrections for multiple comparisons showed the LIN + NR had significantly better SNRs than the other two conditions. Also, HA 1 and HA 3 had statistically better SNRs than HA 2 in both WDRC conditions, but HA 1 was poorer than HA 2 in the LIN + NR condition.



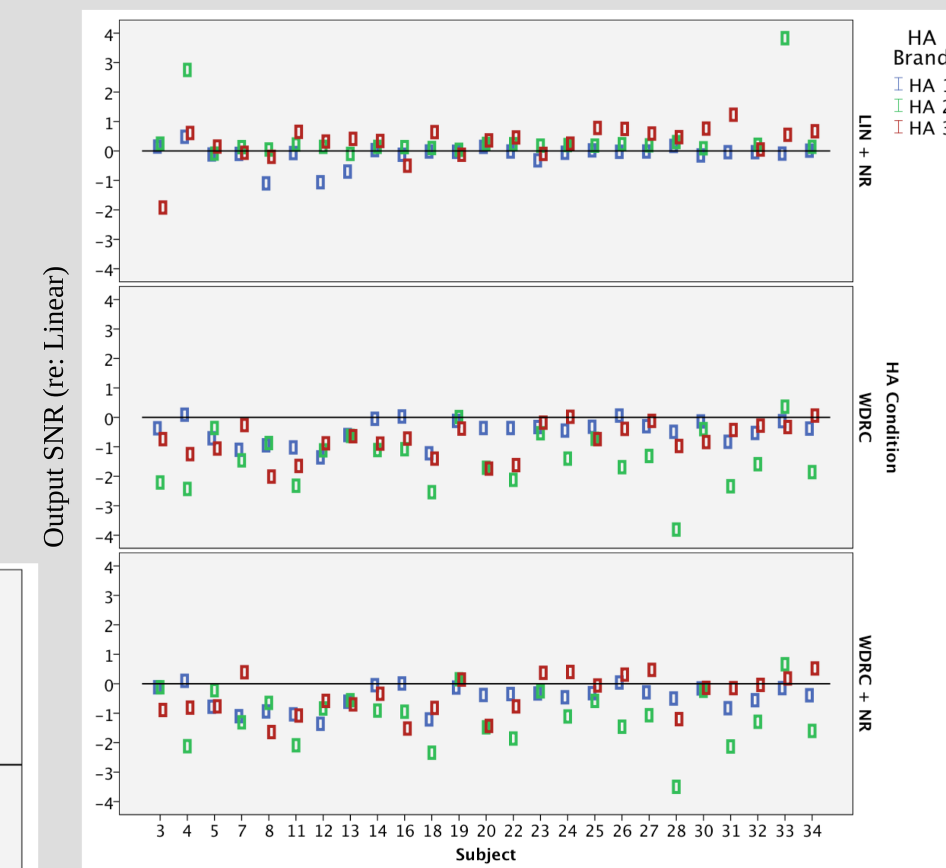


Figure 4. The amount of change in SNR (re: linear) generated by activation of algorithms for the 30ms window length for each subject. There was less than .5 dB difference between the SNR calculated with 120 and 30 ms window lengths (see Figure 5).

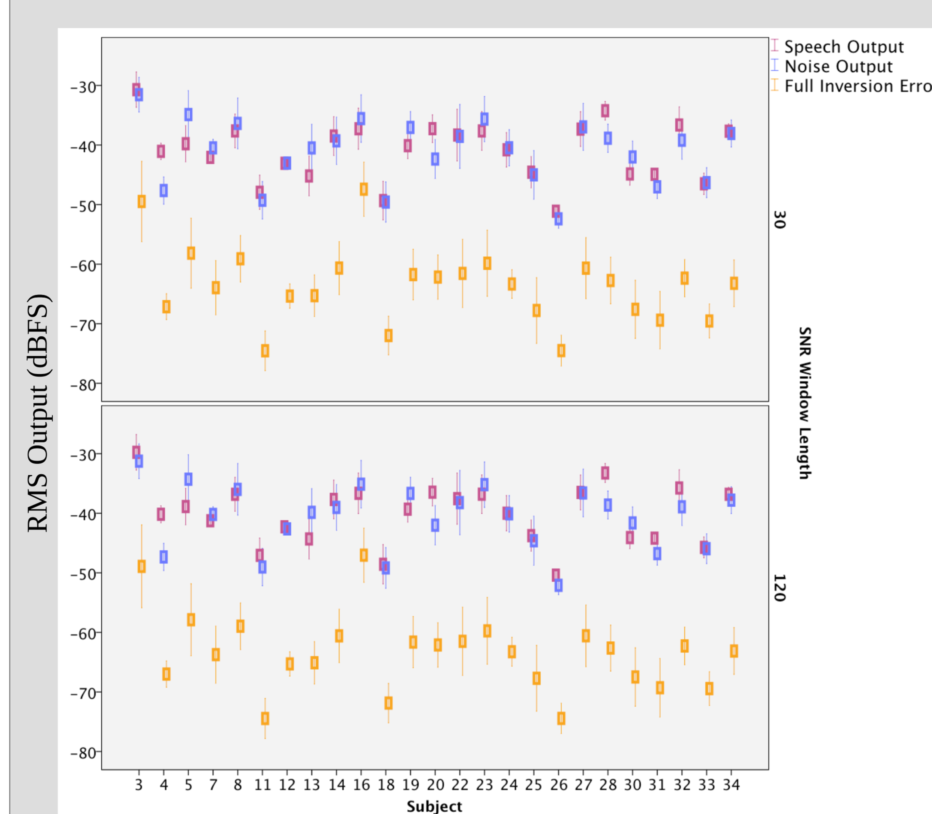


Figure 5. Displayed are three output levels for each subject, collapsed across HA conditions. The speech and noise outputs are the signals extracted with the Hagerman technique. The full inversion error is the residual sound left after using the Hagerman technique with 180° out of phase recordings. There was very little difference between the 30 and 120 ms calculation, demonstrated statistically with an ANOVA comparing window lengths of the extracted speech, noise, and error signal (p > 0.11).

Ideally, there would be a wide separation between the error and the extracted signals, as was the case in these results. The amount of attenuation obtained across subjects and conditions was 22.6 dB (SD=4.6) for the speech output and 22.5 (SD=3.8) for the noise output.

Conclusions

- The amount of change in output SNR with activation of HA algorithms was very small. On average, the LIN + NR condition tended to improve the SNR, while the WDRC and WDRC + NR conditions tended to impede the SNR, compared to the LIN condition. The amount of change varied with manufacturer (Fig 3). Furthermore, there was very little difference between output levels for 120 and 30 ms.
- To understand the sources of variance between individual fittings, the individual's pure-tone average (PTA) and approximate SNR-50 were correlated to their output SNR (re: linear). No significant correlations were found for either variable.
- Although the small differences in SNR were statistically significant, it's unknown whether these changes are perceptually relevant (work in progress). It's been noted that significant improvements in speech perception have been shown with only a 1 dB improvement in SNR[7,8].
- One type of error (attenuation) from using Hagerman's phase-inversion technique with individual fittings was calculated and found to satisfy expectations for all but one fitting (subject 16).

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