The relationship between the Hagerman-derived signal-to-noise ratio and speech perception

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INTRODUCTION

Despite appropriately selected and programmed hearing aids (HA), many HA users continue to experience difficulty understanding speech in noise. One hypothesis is that aided speech intelligibility is partly dependent on the relationship between signals and noise at the output of the hearing aid. Recent findings in neuroscience show that neural codes are disrupted by amplified noise.[1] Cortical neurons have been shown to be sensitive to the relative signal-to-noise ratio (SNR), rather than stimulus level.[2] The purpose of this on-going study is to investigate the functional significance of varying the SNR at the output of the hearing aid in normal hearing and hearing impaired listeners. Research has shown that as the SNR improves at the input to the auditory system, speech perception also improves.[3] However, the SNR at the output stage of the hearing aid has rarely been studied, due to difficulty separating the speech from noise signals once mixed by the hearing aid processor. A recently developed technique[4] facilitates separation of speech from noise, and subsequently allows for SNR estimation at the HA output.

Research Questions:

1) **Does HA processing modify the SNR at the HA output?**
2) **Is the change in SNR made by HA algorithms related to speech perception on the Hearing in Noise Test (HINT) and Connected Speech Test (CST)?[5,6]**

STUDY DESIGN

Seven individuals with normal hearing (NH) and six individuals with impaired hearing (HI) have been recruited so far. Individuals with conductive hearing loss and those with threshold levels poorer than 75 dB HL were excluded.

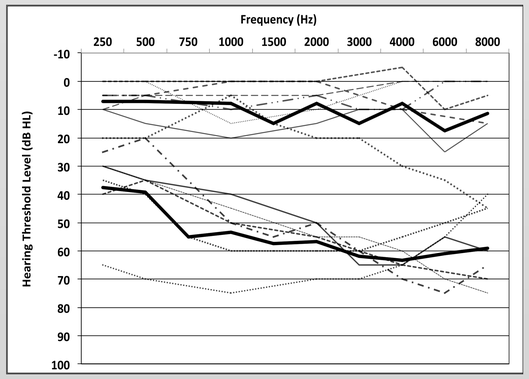


Figure 1. Mean (thick lines) and individual (thin lines) hearing threshold levels for test ears.

Group	Age (yrs)	HA user	Test ear	SNR-50
NH	23	No	Left	-3.2 (HINT)
NH	23	No	Left	-1.8 (HINT)
NH	29	No	Left	-3 (HINT)
NH	23	No	Right	-2
NH	67	No	Left	1
NH	46	No	Right	-1
NH	78	No	Right	-1
HI	23	Yes	Left	15*
HI	23	Yes	Left	2
HI	82	Yes	Left	8
HI	78	Yes	Right	0
HI	60	Yes	Right	1
HI	78	No (owns)	Right	2
*Dropped from study due to difficulty completing speech perception task				

Hearing Aids

Three behind-the-ear hearing aids with standard ear hooks were coupled to either a comply tip or the individuals' own earmold (with vent occluded) for testing. Each aid was programmed to match real ear NAL-NL1 targets as close as possible for all subjects. The MPO was set at the highest level without discomfort (verified subjectively and with a 90dB pure tone sweep). Four HA processing conditions were tested: linear (LIN), LIN + noise reduction (NR), wide dynamic range compression (WDRC), and WDRC + NR. All other features were disabled, if accessible.

Speech Perception in Noise

Pilot testing with 3 NH subjects was performed with the Hearing in Noise Test (HINT). Subsequent testing was completed using two pairs of Connected Speech Test (CST) in each HA condition. Sentences were presented at 65 dB SPL and noise was presented to match the individual's SNR for 50% correct. All stimuli was presented at 0 degrees azimuth.

Hagerman-derived SNR at the HA Output

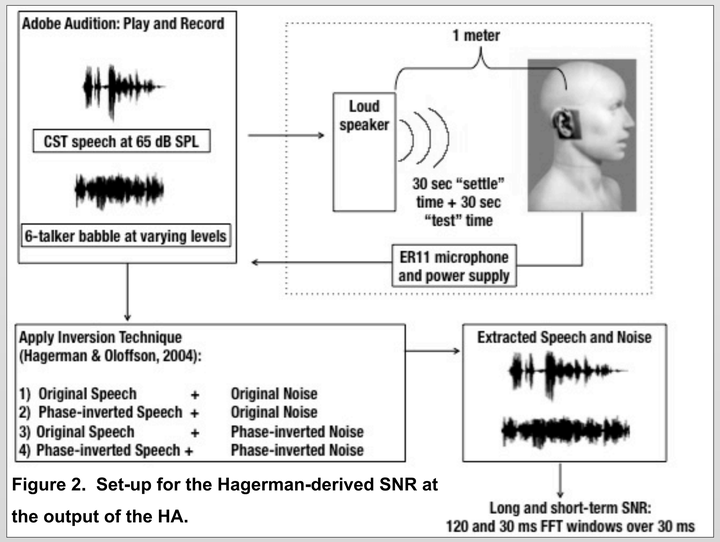
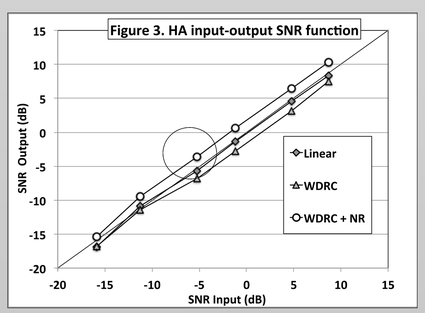


Figure 2. Set-up for the Hagerman-derived SNR at the output of the HA.

Hagerman's phase-inversion technique separates speech and noise at the output of the hearing aid. Four recordings were made in each HA condition (Fig 2). Adding particular recordings would cancel the phase-inverted signal and leave the extracted signal of interested (e.g., adding recordings 1 and 2 in Fig. 2 would cancel the speech and leave the noise remaining).

1) Do HA algorithms modify the SNR at the HA output?

After signals are extracted, the long- and short-term levels of the speech and noise signals were calculated over 30 seconds. All aids and settings piloted generally followed the trend in Fig 3: at the same input SNR, the output SNR can change by 5 dB depending on HA processing.



2) Do SNR changes at the output of a HA relate to changes in speech perception?

Hearing in Noise Test

For 3 NH listeners, speech perception on the HINT is plotted as a function of SNR at the output of two hearing aids (Fig 4). The SNR was manipulated by activation of HA algorithms (WDRC and NR). Preliminary results suggest that as the SNR improves at the HA output, speech perception also tends to improve.

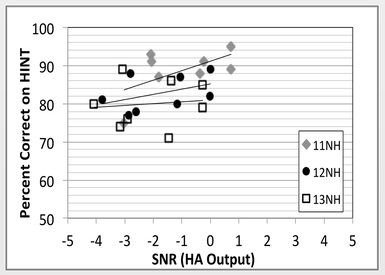


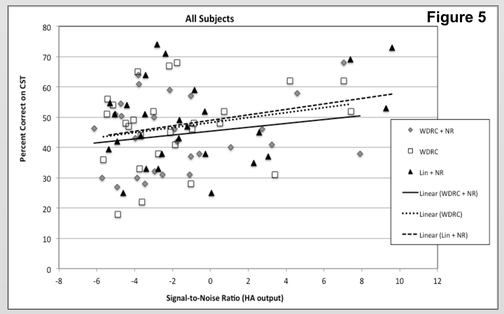
Fig 4. Speech perception on the HINT improves as SNR improves at HA output.

Connected Speech Test

For the remaining 4 NH and 5 HI subjects, the SNR at the HA output was correlated with speech perception scores on the CST. Each subject was tested at their own SNR-50. Figures 5 shows preliminary data with a trend towards improving speech perception as SNR at the HA output improves for all subjects, as expected. This relationship appears to hold true regardless of the type of HA processing making the SNR change.

Figures 6 & 7 show individual speech perception scores as a function of SNR at the HA output (re: linear). Regression lines for each subject highlight that some listeners receive more benefit from SNR improvements than others.

Figure 5



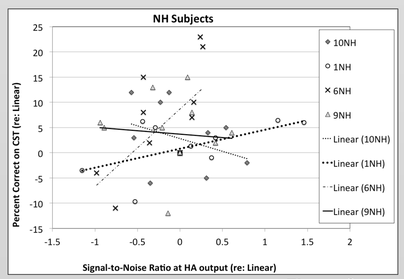


Figure 6

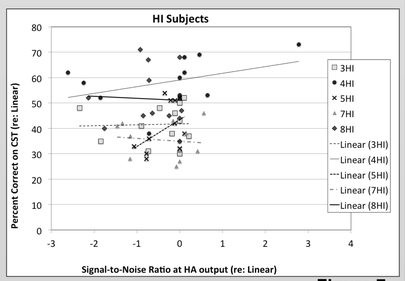


Figure 7

CONCLUSIONS

- HA processing can change the SNR by 0-5 dB based on the aids used in this study. WDRC tends to reduce the SNR by up to 2 dB, while NR tends to improve it by 3 dB.
- Our preliminary data show that as SNR improves at the output of the HA, speech perception also improves. The type of hearing aid processing making the SNR change does not appear to greatly influence this relationship.
- Individual differences in benefit from SNR improvements exist. Future directions will explore whether this is due to differences in auditory processing between individuals, or from other distortions made by the HA processing.

ACKNOWLEDGEMENTS

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