Comparing Hearing Aid Algorithm Performance Using Simulated Performance Intensity Functions

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Research Question: Can a computational model predict speech intelligibility for aided hearing impaired listeners?

Measuring speech intelligibility for different hearing aid fitting methods in a simulated environment would allow rapid prototyping and early design assessment.

A simulated performance intensity function (SPIF) test methodology has been developed to allow experimentation using an auditory nerve (AN) model to predict listeners' phoneme recognition. The test discriminates between normal hearing and progressively degrading levels of sensorineural hearing loss.

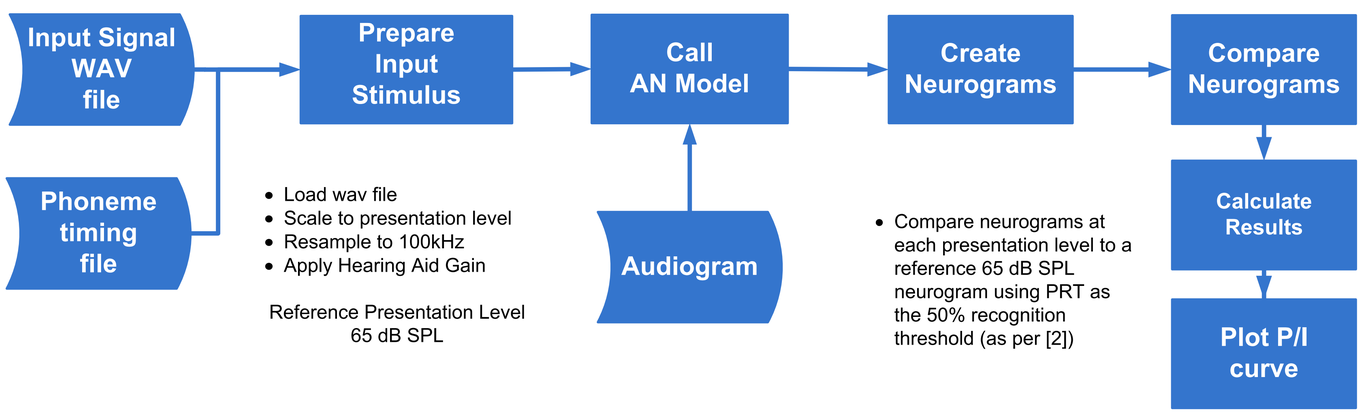
Auditory nerve discharge patterns, presented as neurograms, can be subjectively ranked by visual inspection. Here, subjective inspection is substituted with an automated ranking using a new image quality metric that can quantify neurogram degradation in a consistent manner.

Method

This work reproduces the test results of a range real hearing impaired subjects in unaided and aided scenarios, using a simulation.

Simulated Performance Intensity Function listener tests using CVC words were carried out using the Zilany et al. (2009) AN model to simulate subjects with SNHL in unaided and NAL-RP and DSL 4.0 aided scenarios.

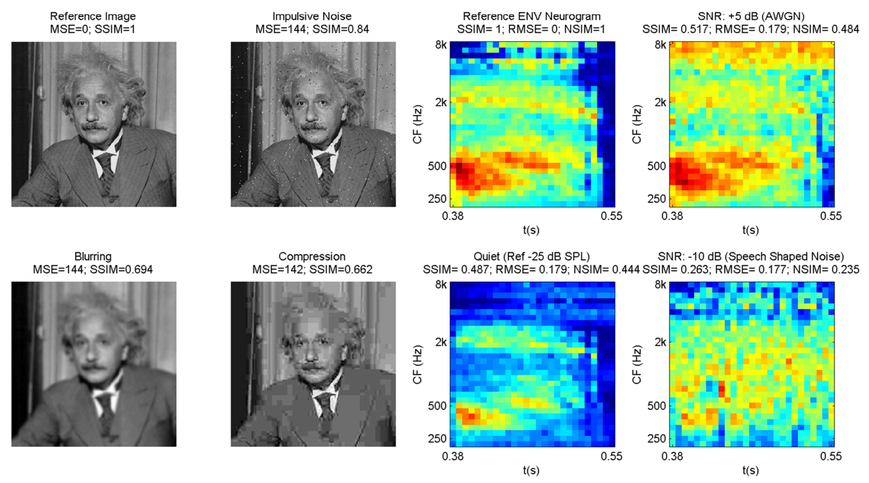
The SPIF procedure mimics that of a real listener test. The human listener is substituted with the AN model and NSIM scores are used to assess neurogram degradation and to predict phoneme discrimination.

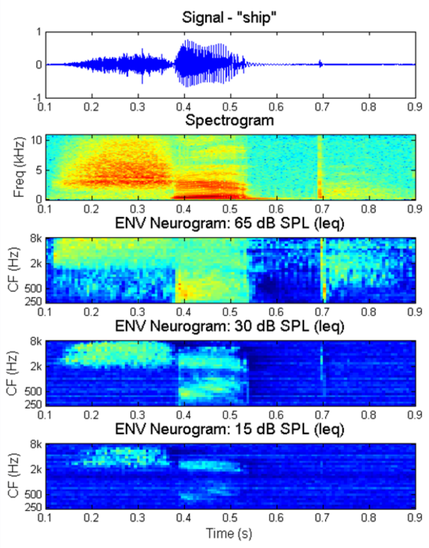


Neurogram Similarity Index Measure (NSIM)

The Neurogram Similarity Index Measure (NSIM) is a simplified and adapted version of structural similarity (SSIM; Wang et al.,2004), an image similarity metric developed by for measuring image quality in JPEG compression. The NSIM between two neurograms, the reference, r, and the degraded, d, is:

$$N(r,d) = l(r,d)\cdot s(r,d) = \frac{2\mu_r\mu_d + C_1}{\mu_r^2 + \mu_d^2 + C_1}\cdot\frac{\sigma_{rd} + C_2}{\sigma_r\sigma_d + C_2}$$



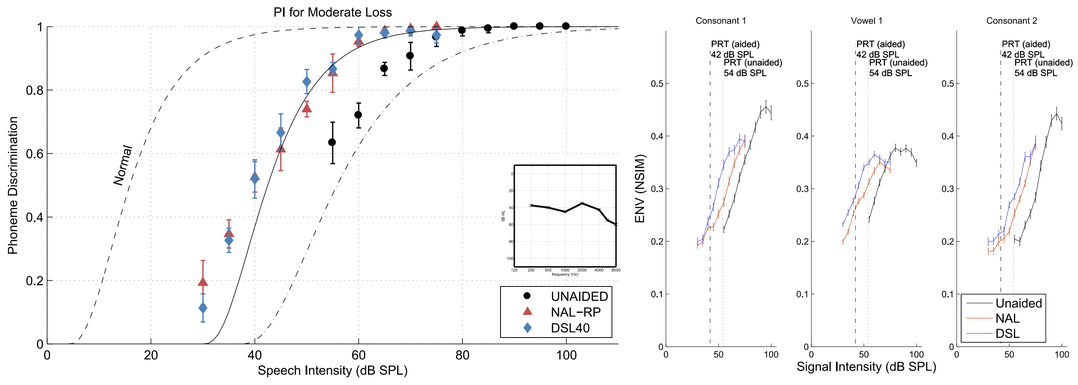


CVC word, "ship", Reference 65 dB SPL signal and spectrogram; neurograms for 65, 30 and 15 dB SPL.

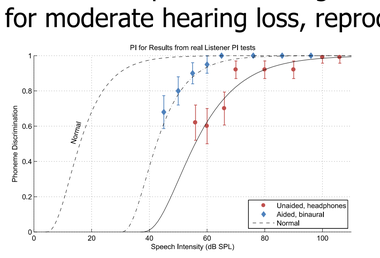
Comparisons between neurograms using NSIM gives more realistic results than simple point to point metrics like relative mean squared error (RMSE). Above is an illustration of using SSIM to compare images and NSIM to compare neurograms. The mean squared error results are almost identical for each degraded image, scoring them as comparably similar.

Results and Discussion

A Flat, Moderate, Sensorineural Hearing Loss



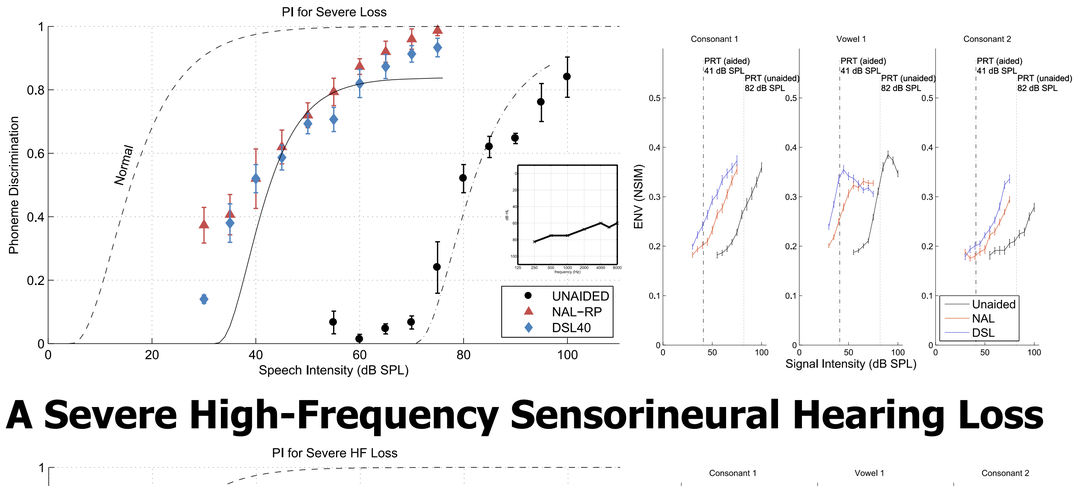
Left: Simulated PI functions calculated from NSIM results with audiogram inset. Right: NSIM Results with phoneme recognition threshold (PRT) marked. Belowe: Actual listener test results for moderate hearing loss, reproduced from Boothroyd (2008)



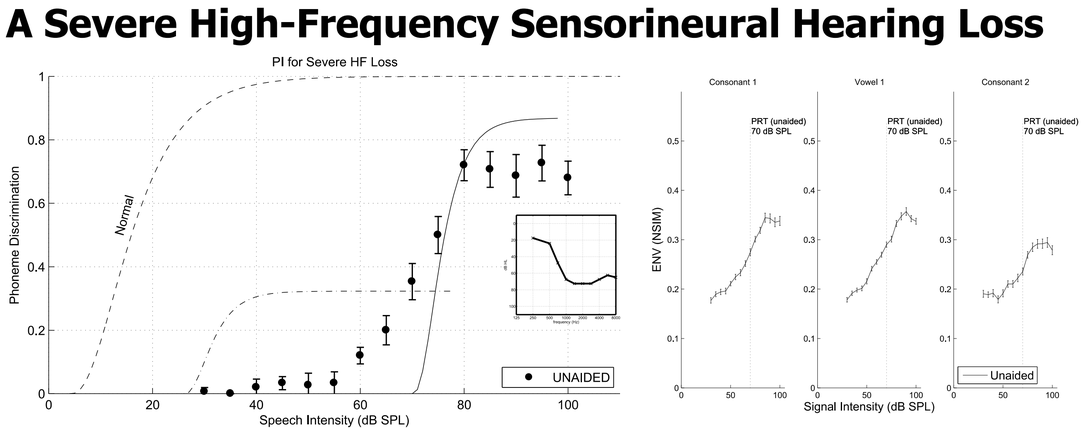
The simulated results correlate within comparable error margins to the real listener test performance intensity functions.

The results demonstrate that a Simulated Performance Intensity Function can predict speech intelligibility and produce results that closely follow human test results for listeners with SNHL. There was little to differentiate the intelligibility results between the fitting algorithms.

A Flat Severe Sensorineural Loss



A Severe High-Frequency Sensorineural Hearing Loss



References

[1] Zilany M.S.A., Bruce I.C., Nelson P.C. & Carney L.H. 2009. A phenomenological model of the synapse between the inner hair cell and auditory nerve: Long-term adaptation with power-law dynamics. The Journal of the Acoustical Society of America, 126, 2390-2412.
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