Individual differences in self-adjusted gain for noisy rooms: effects on audibility

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Introduction

- Noisy restaurants are among the most challenging listening situations for hearing aid users, but little data are available to guide hearing aid fitting for noisy situations.
- Anecdotal evidence suggests that listeners may value **comfort over speech intelligibility** as noise increases.
- Ear Machine ™ technology allows users to adjust all parameters of multiband compression. MSP lab facility allows replication of noisy real-world settings, and allows experimental control of SNR in those backgrounds, along with direct observation of users' preferences for settings as SNR is experimentally varied.
- Previous results indicated that as signal-to-noise ratio (SNR) became less favorable, some (but not all) listeners self-adjusted gain considerably, possibly sacrificing intelligibility for comfort.
- Data are shown here from listeners with mild to moderate sensorineural hearing loss who self-adjusted amplification parameters in laboratory simulated restaurant environments.
- Estimates of individual audibility were computed post-hoc and were converted to predicted intelligibility scores (% correct).
- Most listeners selected lower gain settings at SNRs poorer than those that yield intelligibility of about 80% .
- For a proportion of the listeners, this resulted in reduced intelligibility at challenging SNRs.
- **Overall, the data provide information about individual differences regarding the trade-off between reducing noise and maximizing intelligibility.**

Our primary research question is: **When listeners self-adjust gain, do they sacrifice intelligibility for comfort in noise?**

Previous Findings

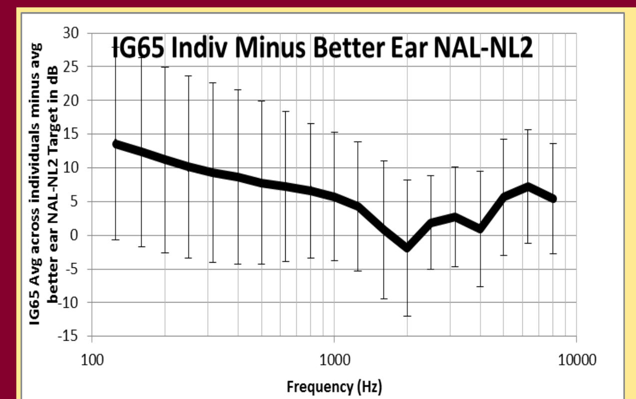


Figure 1. Average insertion gain for 65 dB input minus better ear NAL-NL2 targets. Error bars = +/- 1 sd

Previous findings from our group (reported at AAS 2014 and IHCON 2014) showed individual variability in the way listeners adjusted gain as follows:

- **In quiet** (+15 SNR shown in Fig 1 left), on average, users gave themselves slightly more gain than NAL-NL2. 4 freq avg = 3 dB
- More low-frequency gain was preferred versus NAL-NL2 target
- Considerable variability was seen.

As noise increased to negative SNRs most listeners turned down the gain significantly, shown in Fig 2 below, right.

- Gain selected for -10 dB SNR was different from the rest of the SNRs.
- At -10 SNR, when the speech is not very detectable, on average listeners reduced gain more, presumably to increase comfort.
- There was considerable variability in the results, and the variability increased as SNR decreased.
  - Some listeners turn gain down
  - Others make small changes
  - Others continue to turn gain up, even in negative SNRs, presumably to try to understand the speech.

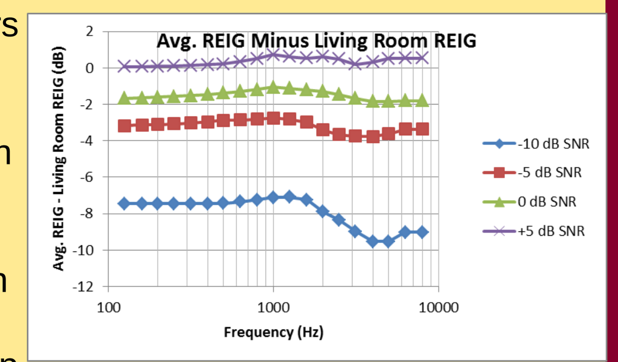


Figure 2. REIG (re: IG for quiet) for each SNR averaged across 10 listeners. Self-selected input-referred gain for the +15 condition was subtracted from input-referred gain for each SNR.

Gain Change vs. Predicted %

When the SNR (and overall level) increased such that intelligibility fell below 80%, subjects started turning the gain down, as seen in the scatterplot in Figure 6 below. Differences between self-adjusted and NAL prescribed gain are plotted as a function of the predicted percent correct.

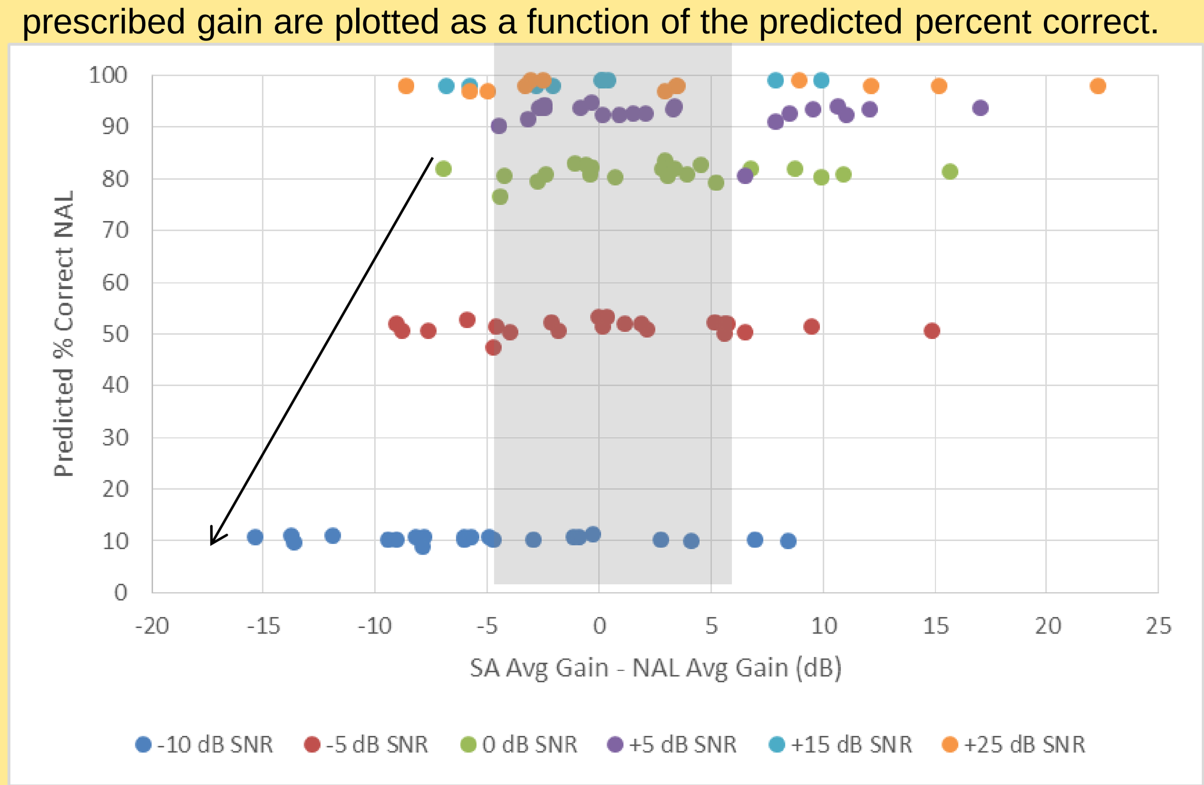


Figure 5 Predicted percent correct is shown as a function of the difference between self-adjusted (SA) gain and NAL-NL2 prescribed gain. The gray area shows +/- 5 dB change.

A great deal of variation in self-adjusted gain is observed, especially when the SNR was least or most favorable. Listeners at times chose 10-20 dB more gain than NAL prescription for quiet conditions, and as much as 15-20 dB less gain for noisy conditions.

Results: Overall Trends

The figure below shows the change in gain along the x-axis as a function of the predicted change in intelligibility for the self-adjusted (SA) vs NAL predicted gain. The gray area shows the range of predicted intelligibility change between +5 and -10%. A few points fall outside that range.

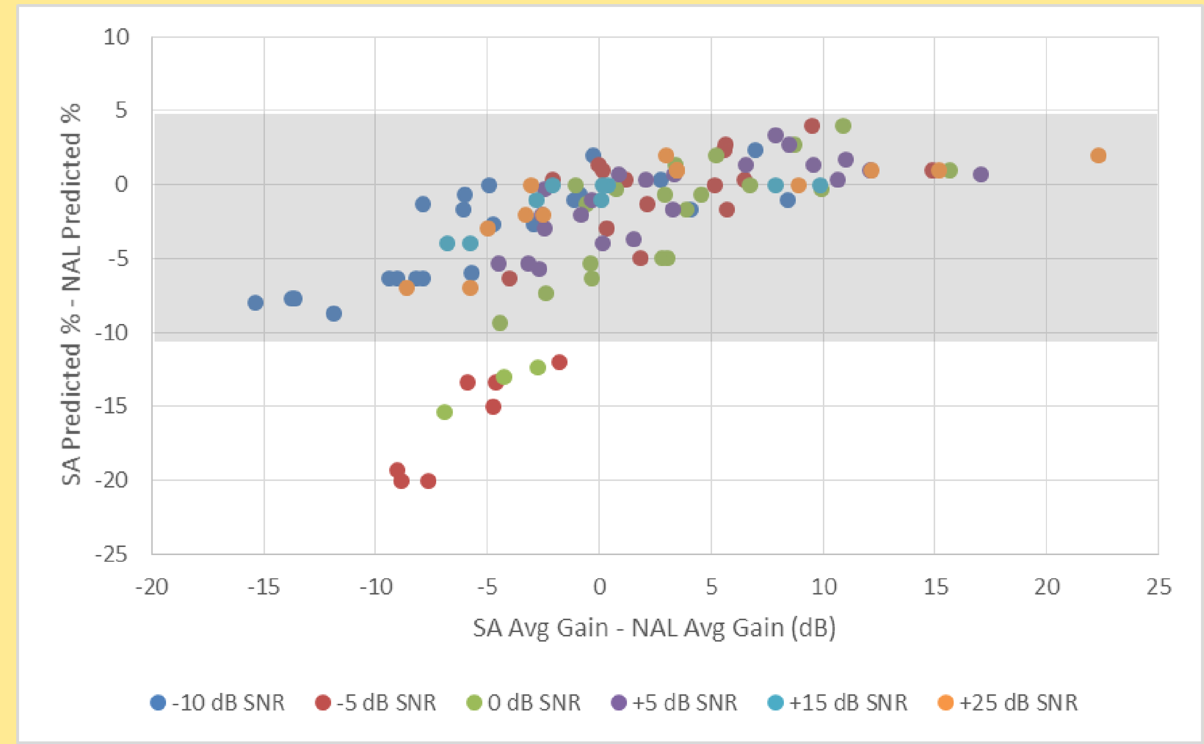


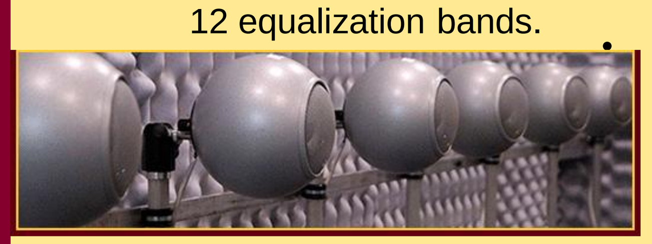
Figure 7 Change in predicted percent correct is shown as a function of the difference between self-adjusted (SA) gain and NAL-NL2 prescribed gain..

- For 0 and -5 dB SNR conditions (shown in green and red symbols) a few listeners reduced the gain by up to 10 dB, resulting in a 15-20% reduction in intelligibility.
- Gain reductions for -10 dB SNR did not result in change in intelligibility

Equipment and Stimuli

EarMachine

- Subjects used a mobile application, developed by Ear Machine LLC, running on the Apple iOS platform and implemented on an iPod Touch (4).
- Etymotic hf5 earphones with foam tips delivered stimuli to both ears.
- 9-band multiband wide-dynamic range compressor/limiter
  - fast attack and slow release times
  - 12 band equalizer.
  - signal processing was designed to provide a close match to a commercial hearing aid.
- Subjects manipulated 2 controllers on the Ear Machine interface.
  - loudness controller changes gain, compression and limiting parameters in all 9 compression channels simultaneously.
  - fine tuning controller changes overall frequency response in the 12 equalization bands.



- **Laboratory**
  Listeners were tested while seated in the Multisensory Perception Laboratory at the University of Minnesota.
  - 10' by 13' double-walled chamber (Height 8.5')
  - 48-channel speaker array, Anthony Gallo Acoustics - A'Diva ti Speakers.
  - 24 Crown XLS 1500 Power Amplifiers.
  - 3 Lynx Aurora 16 D/A

STIMULI
Speech stimuli were Connected Speech Test (CST, Cox *et al.*, 1987) sentences presented at a level of 53 - 55 dBC, spatialized to match the room acoustics.

Listeners were presented with looping 30-second recordings of the CST
- Trials at -10, -5, 0, and 5 dB SNR for the 3 restaurant noises
- Living room noise was at +15 to +25 dB SNR.

Listeners were instructed to:

Adjust the wheels until you can understand what the woman talking in front of you is saying as clearly as possible.
Go back and forth between the wheels
until you are satisfied that you have the best setting.

Subjects and Methods

- To date, 15 listeners with sensorineural hearing loss participated in the current laboratory experiments.
- Ages ranged from 50 to 80 years (avg 67 yrs).
- No air-bone gap was greater than 15 dB
- Average audiometric data and standard deviations are shown in Fig 3 below

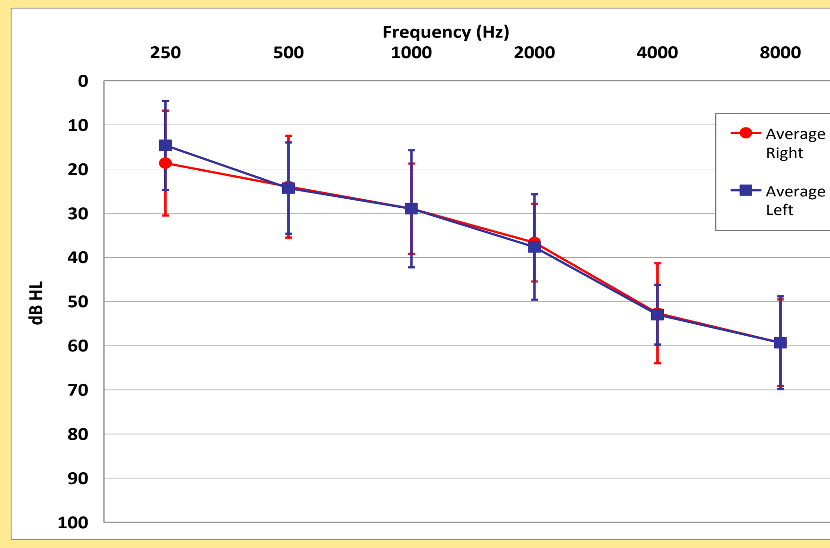


Figure 3. Average audiograms fro 15 participants Error bars = +/- 1 sd

RECD and REUG were measured for each subject so that self-adjusted insertion gain (IG) could be compared to NAL-NL2 targets.

AI was calculated for amplified signals both for **NAL gain** and Self-Adjusted, **SA gain**.
AI estimates were based on the SNR and audibility of the amplified speech within each third-octave band using a 30-dB dynamic range.

AI estimates were transformed to predicted percent correct using the transfer function (Sherbecoe and Studebaker, 2002), shown in Figure 4 at right.

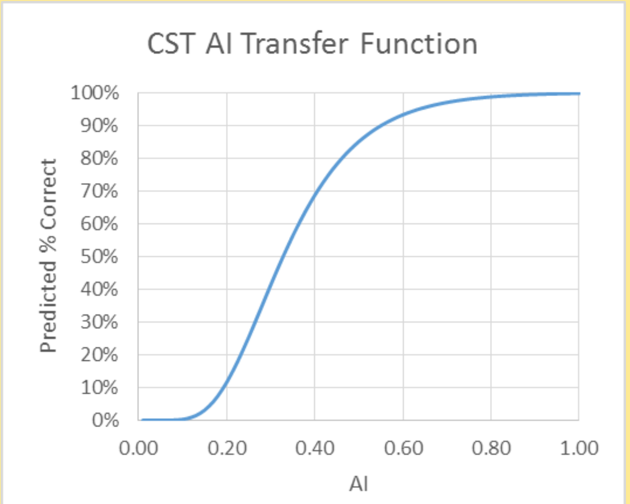
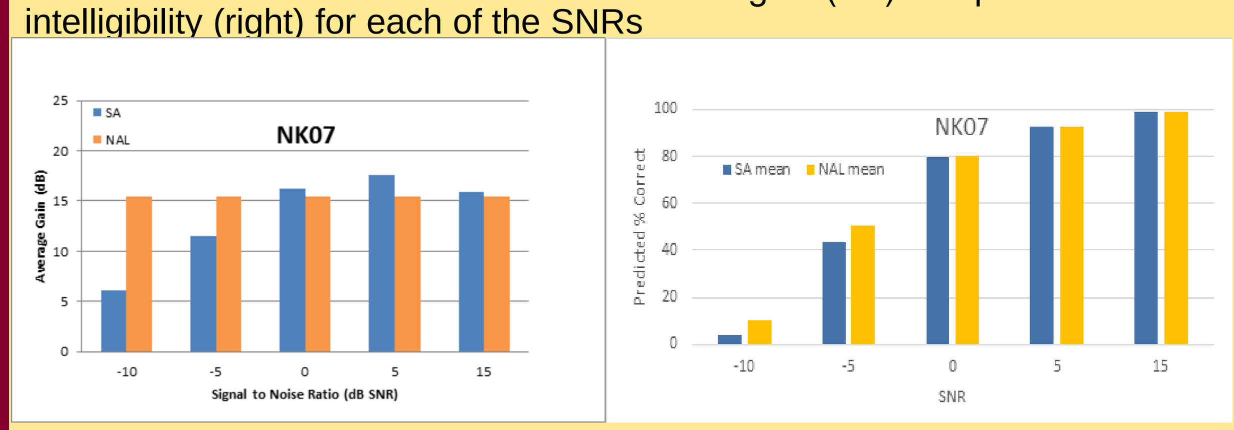


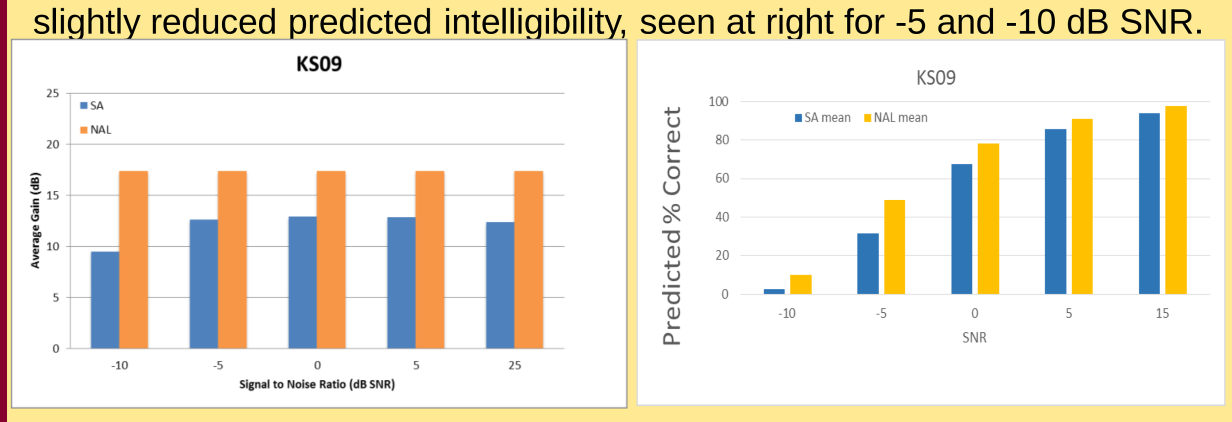
Figure 4. Predicted percent correct is shown as a function of AI for the CST sentences.

Individual Results

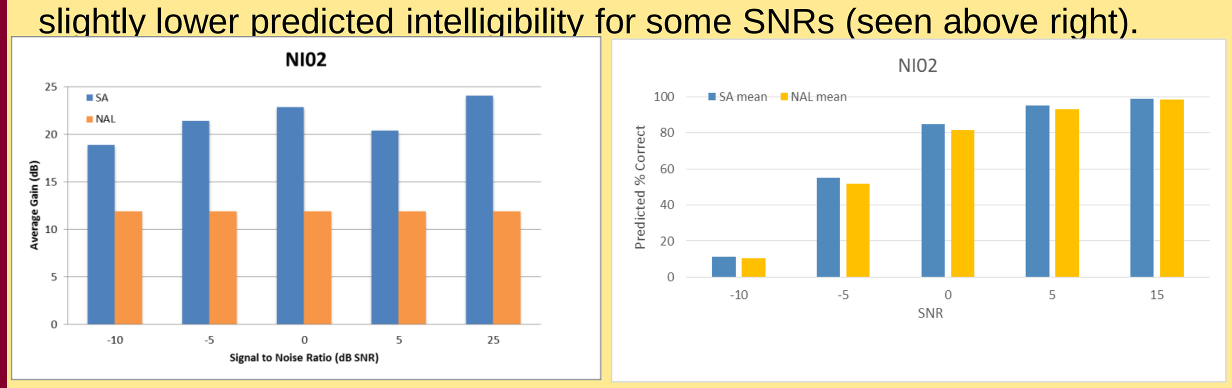
Three individuals' results are shown below for gain (left) and predicted intelligibility (right) for each of the SNRs



Listener NK07 chose slightly more gain than NAL for favorable SNRs but less gain for poorer SNRs. In those conditions gain choices resulted in slightly reduced predicted intelligibility, seen at right for -5 and -10 dB SNR.



Listener KSO9 showed a somewhat different trend in that this listener chose slightly less gain at all SNRs compared to NAL and this resulted in slightly lower predicted intelligibility for some SNRs (seen above right).



Listener NI02 chose more gain than NAL for all SNRs, with a corresponding slight increase in predicted intelligibility.

Figure 6: Gain (left) and resulting **predicted percent correct (right)** are shown as a function of SNR for 3 listeners.

Conclusions

Overall the data showed considerable individual variability in self-adjusted gain, with some listeners trading intelligibility for comfort in certain noise conditions

- At -10 dB SNR, (the poorest SNR and the highest SPL) self- adjusted gain was reduced the most, but it had little effect on intelligibility because intelligibility is already at minimum.
- At 0 and -5 dB SNR, gain was reduced by as much as 10 dB re: NAL-NL2 in a few cases, and it reduced intelligibility by as much as 20% for those subjects who chose to do so. They chose reduced gain (presumably comfort) over intelligibility in these cases.
- At positive SNRs, no participant chose gain that reduced intelligibility, and some even increased gain relative to NAL targets by a bit. There is a wide range of gains around NAL prescription targets (about 18 dB or so) where the intelligibility outcome is the same.

CONCLUSIONS

- In very difficult listening conditions, listeners turned gain down by>10 dB but did not sacrifice intelligibility; the noise was the dominant signal and no amount of gain would improve speech recognition
- In moderately difficult listening conditions (around 0 dB SNR) listeners varied; some reduced gain by 10 dB and sacrificed some intelligibility
- In favorable conditions, listeners varied in their self-adjusted gain but neither improved nor reduced intelligibility

FUTURE DIRECTIONS
Intelligibility testing is underway to confirm the predicted findings.

References / Acknowledgements

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