User self-adjustment of a simulated hearing aid in laboratory versus real-world noise

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Abstract

Noisy environments --- especially noisy restaurants and meeting places -- are among the most challenging for hearing aid users, but little is known about optimal hearing aid settings for those environments. One reason for this is the challenge of evaluating users' listening preferences in real-world environments. This report will focus on validation of a lab environment that replicates noisy real-world environments. Noise levels were measured and environmental recordings were made in three area noisy restaurants and a quiet office. Stereo recordings were convolved with room impulse responses and played in a multisensory lab through 46 loudspeakers. Participants listened using an iPod Touch running a real-time simulation of a multichannel compression hearing aid, with all gain/compression parameters adjustable via a simple user interface (EarMachine). They adjusted hearing aid parameters while listening in the lab at noise levels from 45 to 75 dB A. Participants then went to the original restaurants and made iPod adjustments in the real environment from which the lab simulation was derived. A comparison of participant-adjusted settings from real and simulated situations will be presented. Validation of the lab environment will allow us to conduct future experiments in the laboratory, where stimulus conditions can be controlled much more precisely than they can in real settings.
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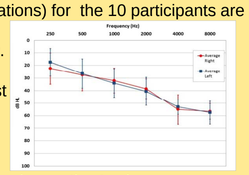
Introduction & Subjects

•Listeners vary in their satisfaction with amplification in noisy environments (e.g., Kochkin, 2010)
•Part of the likely variation in listener amplification preference in noisy settings is the variation across noisy settings themselves (overall level, SNR of target speech to background noise, etc.). These can be difficult to control for in an actual restaurant or other "real world" noisy situation.
•This experiment looked at how hearing-impaired (HI) listeners self-adjusted their amplification device in recorded restaurant noise in a laboratory setting versus how they set their devices in a real-world restaurant setting.
•To date, 10 listeners with sensorineural hearing loss have participated in laboratory experiments.
Five of these listeners have also completed field measures.
Audiograms (mean and standard deviations) for the 10 participants are shown in the table (dB HL)
•Ages 60 to 74 yrs (68.7 average age).
•No air-bone gap greater than 15 dB
•Audiograms completed within the past year



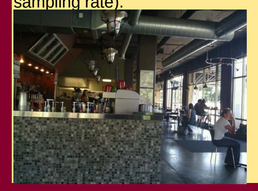
EarMachine

Subjects used a mobile application running on the Apple iOS platform and implemented on an iPod Touch (4th generation). Listeners wore Etymotic hf3 earphones with foam tips. The application was developed by Ear Machine LLC, and consisted of a 9-band multiband wide-dynamic range compressor/limiter with fast attack and slow release times, and a 12 band equalizer. The details of the signal processing were designed to provide a close match to a commercial hearing aid.
Subjects manipulated the two simple controllers on the Ear Machine user interface. Moving the loudness controller changes gain, compression and limiting parameters in all 9 compression channels simultaneously. Moving the fine tuning controller changes overall frequency response in the 12 equalization bands according to an algorithm based on hearing aid users' response to hearing aid sound.

Multi-Sensory Perception Lab

Field recordings were made in a variety of listening locations over the lunch hour. Measures were made in a conference room and three restaurant locations. A photograph of one restaurant is below.

The setup for each set of recordings was a Schoeps CMC6 MK4 cardioid microphone pair in an ORTF configuration and a Roland R-4 portable sound recorder (settings: gain at 3 o'clock, 24-bit quantization, 48.0k sampling rate).



•Laboratory measures were obtained in a 10' by 13' double-walled chamber (Height 8.5')
•It contains a 48-channel speaker array, Anthony Gallo Acoustics - A'Diva ti Speakers
•24 Crown XLS 1500 Power Amplifiers.
•3 Lynx Aurora 16 D/A converters.

The room dimensions for each location are noted below. (L x W x H,).
- Five Guys: 58' x 24' x 9'
- Potbelly: 38' x 30' x 25'
- Purple Onion: 80' x 56' x 13'
- Shevlin Hall Conference Room (living room):16' x 14' x 9'

Recordings were calibrated for presentation from 60- 75 dBC in the lab.

Stimuli and Procedures

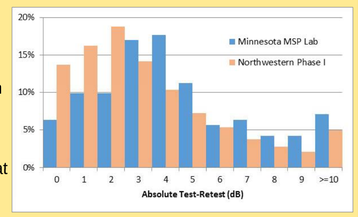
The Connected Speech Test (Cox, Alexander, and Gilmore, 1987) recordings were passed through a filter such that they were spatialized to match the restaurant sizes and estimated reverberation times). During data collection, the CST spatialized to match the Potbelly restaurant was only used during samples of the Potbelly background noise, and the same was true for the other recording locations.

Listeners were presented looping 30-second recordings from 3 restaurants at overall levels of 55, 60, 65, 70 dB C, corresponding to -5, 0, 5 and 10 dB SNR. Living room noise was at +25 dB SNR.
Speech stimuli were Connected Speech Test at nominal level of 65 dBC, spatialized to match the room acoustics.
Listeners were instructed to adjust the settings as follows:

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.

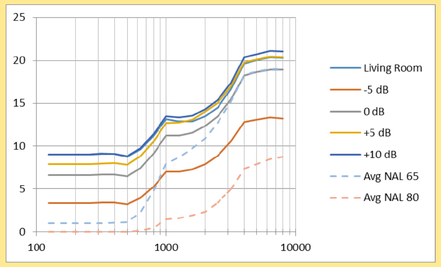
Listeners indicated when they were satisfied with the fit; then the next stimulus was presented
Listeners had at least 1 practice run (of at least 7 trials), followed by 2 repetitions of each SNR (26 trials), randomized without replacement.
Insertion gain for 19 frequencies was noted for each, along with stimulus levels

•Repeated self-adjusted gain settings were compared for the same conditions: (i.e., 0 dB SNR, 65 dB input, "FG" restaurant).
Test-retest results are shown to the right. Test-retest was calculated to be approx 4-5 dB. These data are shown compared to data collected at Northwestern Univ., under more controlled conditions.



Lab Measures: IG v. NAL Targets

The figure below shows average self-adjusted insertion gain by frequency for the ten participants.
Insertion gain for the different lab-simulated noise conditions are shown in solid lines, including SNRs of +25 (living room), +10, +5, 0 and -5.
The level of the target speech (CST) in all of these conditions was fixed at 65 dB SPL.
Average NAL-NL2 targets are shown in dashed lines for 65 and 80 dB inputs.

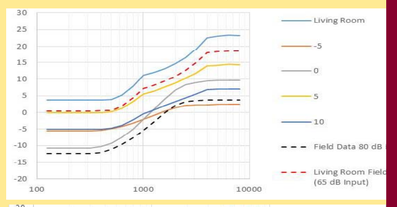


Overall, listeners adjusted gain in a manner predicted by the NAL targets.
More gain was selected for the quieter conditions.
Most listeners decreased gain when noise was presented at -5 dB SNR.

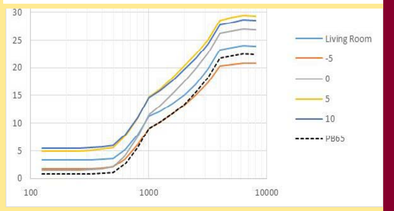
Individual Variability

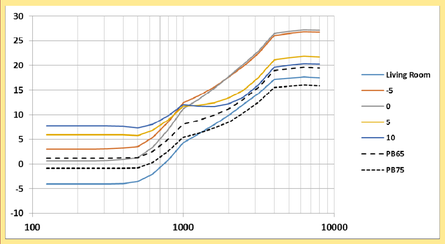
Self-adjusted gain setting trends were similar across listeners, with some exceptions. Insertion gain by frequency is shown below for three individual listeners for five laboratory noise conditions (varying SNR shown in solid lines) and two field restaurant conditions (dashed lines.)

Most participants in most simulated noise conditions turned gain down as background noise levels increased, like those shown at right.



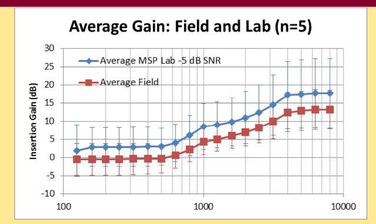
Some selected quite large differences in gain from quiet to noisy conditions (as in upper right); others self-selected only small changes in gain as noise increased (as in lower right).



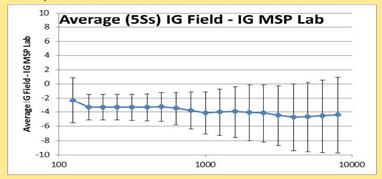


The participant shown at left increased gain in noise, even when background noise levels reached 0 and -5 dB SNR.

Lab vs. Field IG Measures



•Exact comparisons of field and laboratory insertion gain settings are challenging; overall SPL values were most similar for the field and the MSP lab at -5 dB SNR (lab) settings.
•On average, laboratory (-5 dB SNR) and field IG measures are similar for the first 5 subjects.
•Overall to date, listeners self-adjust gain settings to be few dB greater in the lab than in the field, and this difference is consistent across frequencies.



Conclusions

•Laboratory simulations of restaurant noise conditions are validated by the first 5 subjects. Self- adjust amplification settings were similar in real restaurants and simulated ones.

•Listeners select a few dB more gain in the lab than in the field.
•We anticipate that we will be able to accurately interpolate from laboratory settings (which are much more controllable) to field settings.
•Test-retest within the laboratory setting was satisfactory.
•Differences between field and laboratory settings fell generally within the test-retest differences.
•When self-adjusting gain, most subjects set gain parameters for quiet conditions (quiet conference room through about +5 dB SNR) about the same, applying the most gain to those quiet settings.
•When listening conditions get poorer (at 0 and -5 dB SNR) listeners behave differently .
- •Some turn gain down significantly.
- •Others make small changes in gain
- •Others continue to turn gain up, even in negative SNRs, presumably to try to understand the speech.

FUTURE DIRECTIONS
•Additional data collection is underway to investigate individual differences between NAL targets and self-adjusted gain and to determine if these result in differences in speech intelligibility and/or satisfaction with overall sound quality in noisy situations.

References

Cox RM, Alexander GC, Gilmore C.(1987) Development of the Connected Speech Test (CST). Ear Hear. 8(5 Suppl):119S-126S.

Kochkin, S. (2010). MarkeTrak VIII: Consumer satisfaction with hearing aids is slowly increasing. The Hearing Journal 63: 19-27.

VanTasell, D.J. and Sabin, A., Ear Machine, http://www.earmachine.com/.