Acceptable Hearing Aid Throughput Delay For Listeners with Hearing Loss Under Noisy Conditions

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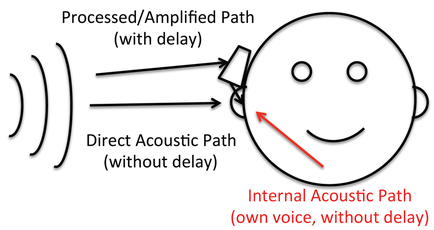
Introduction

Hearing aid processing (e.g. noise reduction, binaural beamforming, etc.), remote microphone communication, and the overall number of frequency bands each contribute to the throughput delay of digital hearing aids.



Established practice among hearing aid manufacturers is to limit the degree of hearing aid throughput delay to 10 msec[3]. Unfortunately, these limits can severely impact the amount of processing that can take place in hearing aids, especially when studies suggest that longer delays would actually be acceptable to hearing aid users[1,2,5].

Previous studies have looked at the effect of delay, exclusively, in high signal-to-noise ratio conditions. We have previously reported that most normal-hearing participants found delays of at least 20 msec to be acceptable in real-world, noisy listening conditions[4]. The current study extends our previous research to include participants with hearing loss.

Methods

Research Questions:

When comparing hearing aid throughput delays of 4.5, 15, 20, and 25 msec in background noise levels greater than 70 dB SPL:

- Are hearing-impaired listeners able to detect differences between the delays?
- Do hearing-impaired listeners find the delays acceptable?

Participants:

Nine participants (n=9) with hearing loss were included in the study. Five (n=5) participants wore open-fit hearing aid devices while four participants (n=4) wore devices with a 1mm acoustic vent, as appropriate for the degree and configuration of the individual participant's hearing loss.

Methods (Cont.)

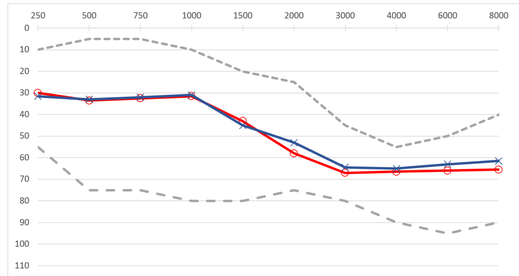


Figure 1. The average air-conduction thresholds of participants is shown. The participants had hearing loss configurations ranging from mild to profound degrees of hearing impairment. The red line represents hearing thresholds of the participants' right ears while the blue line represents the hearing thresholds of the left ears. The dotted lines indicate the maximum and minimum hearing thresholds, for either the right or left side, of all participants at each octave and inter-octave frequency (250-8000Hz).

Hearing Aid Devices:

- Starkey receiver-in-canal hearing aids were prepared with firmware that allowed throughput delay to be parameterized
- Individual gain settings were fit and verified to meet e-STAT prescription targets based upon the participants' individual hearing thresholds
- Four memories were programmed identically except for throughput delay:
  - Memory 1 contained the standard 4.5 msec delay
  - Memories 2-4 contained randomized delays of 15, 20, and 25 msec
- The devices were set to the "Omni Directional" microphone mode

Procedure:

- Participants compared hearing aid processing delays, which ranged from 4.5 to 25 msec, in listening conditions where the ambient noise level was ≥70 dB SPL
- Perceptual sound quality was rated, independently, for the participant's own voice as well as for the speech of others
- The subjective ratings were based upon the relative differences between the 15, 20, and 25 msec conditions in comparison to the 4.5 msec condition
- For each rating, the participants assessed the ambient noise level using a calibrated sound meter App on an Apple iPod Touch

Results

Detectable differences:

- Less than half of the participants were able to detect differences in throughput delay, even at the longest delay of 25 msec

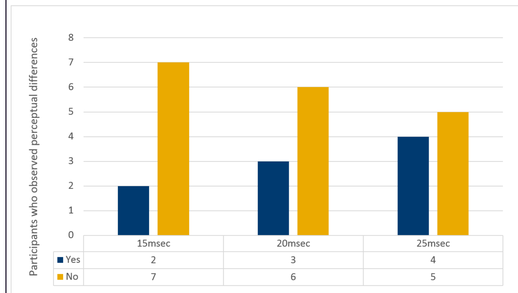


Figure 2. Participants' overall sensitivity to increases in throughput delay is plotted for each experimental condition (15, 20, and 25 msec). The number of participants who perceived differences between the 4.5 msec condition & the experimental condition increased as a function of the throughput delay.

Acceptability of perceived differences:

- For those who could detect differences across the delay conditions, there was a trend for the 25 msec delay condition to be somewhat less acceptable than the other delay conditions

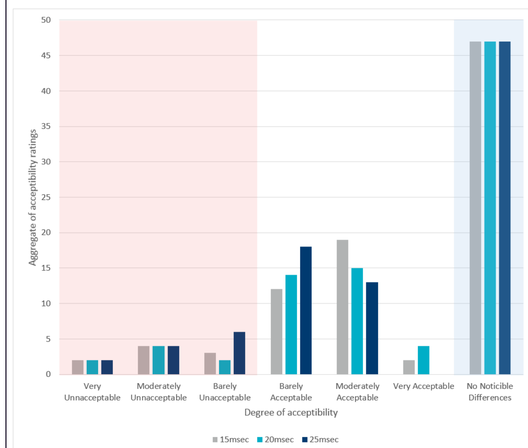


Figure 3. Perceived differences in throughput delay are plotted as a function of degree of acceptability. Difference ratings ranging from "No detectable differences" (0) to "Differences are very unacceptable" (7) are plotted for three latency experimental conditions (15, 20, and 25 msec) as compared to the 4.5 msec throughput delay condition. The shaded regions highlight the ranges of acceptability: blue = "no difference"; white = "acceptable differences"; red = "unacceptable differences".

Results (cont.)

Relationship with ambient noise level:

- Detectable differences were increasingly reported as the degree of throughput delay increased, particularly when ambient noise levels were at their lowest

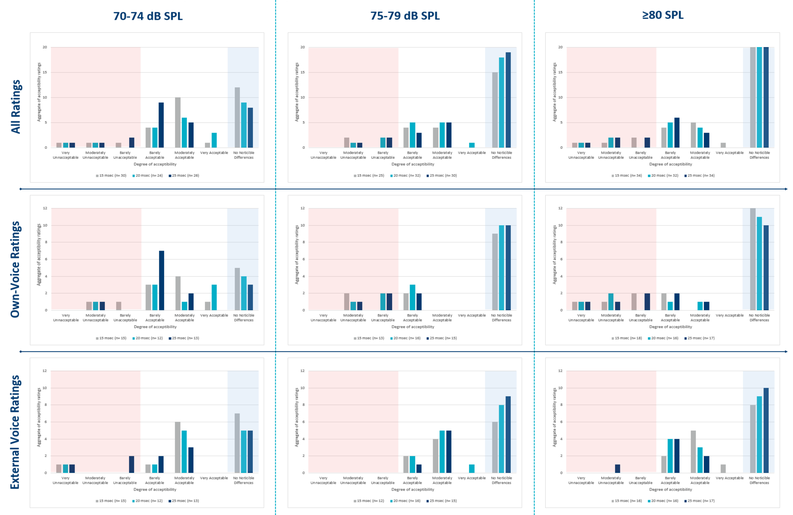


Figure 4. Acceptability of perceived differences in throughput delay, is plotted as a function of ambient noise level. Difference ratings ranging from "No detectable differences" (0) to "Differences are very unacceptable" (7) are plotted for three latency experimental conditions (15, 20, and 25 msec) as compared to the 4.5 msec throughput delay condition for each segmented ambient noise-level range. The first row of graphs are total ratings for each experimental latency condition. The second row and third row of graphs plot the ratings of own-voice and external voices, separately, for each experimental latency condition. The shaded regions highlight the ranges of acceptability: blue = "no difference"; white = "acceptable differences"; red = "unacceptable differences".

Summary

- Less than half of the participants were able to detect differences in throughput delay, even at the longest delay of 25 msec
- When differences in throughput delay were detected, most were still rated as being "acceptable" to the hearing impaired listeners
- Detectable differences were increasingly reported as the degree of throughput delay increased, particularly when ambient noise levels were at their lowest
- Our data suggest that, under noisy conditions, hearing aid wearers will tolerate throughput delays that are longer than those conventionally referenced
- Future work will examine the impacts of throughput delay on speech intelligibility with changing environmental conditions

References

1. Agnew, J., & Thornton, J.M. (2000). Just noticeable and objectionable group delays in digital hearing aids. Journal of the American Academy of Audiology, 11(6), 330–336.
2. Cole, B. (2005). Group Delay and Processing Delay In Hearing Aids The Facts and the Fantasies. Audio Note 3.
3. Herbig, R., & Chalupper, J. (2010). Acceptable processing delay in digital hearing aids, 17(1), 28–31. Retrieved from http://www.hearingreview.com/2010/01/acceptable-processing-delay-in-digital-hearing-aids/
4. McKinney, M.F., Burwinkel, J.R., and Zhang, T. (2015). *Maximum Acceptable Delay in Hearing Aids Under Noisy Conditions*. Poster session presented at the Annual Scientific and Technology Conference of the American Auditory Society, Scottsdale, AZ.
5. Stone, M.A., & Moore, B.C.J. (2002). Tolerable hearing aid delays. II. Estimation Of limits imposed during speech production. Ear and Hearing, 23(4), 325–338.