Maximum Acceptable Delay in Hearing Aids Under Noisy Conditions

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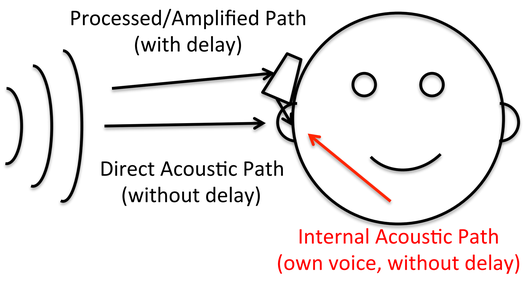
Starkey Hearing Technologies

Introduction

- Established practice and previous literature impose a 10 msec limit on hearing-aid throughput delay (Herbig & Chalupper 2010).
- Larger delays are objectionable due to interaction between amplified and direct acoustic paths.
- The delay limit severely impacts the amount of processing that can take place in a hearing aid.
- Previous studies looked at the effect of delay in laboratory conditions using a high signal-to-noise ratio.
- The current study tests the validity of this delay limit under noisy, real-world listening conditions.

Background



- Combinations of acoustic paths with different delays contribute to (in)tolerances.
- Tolerable delays during speech production (Stone and Moore, 2002)
  - 14-30 msec
  - Acclimatization is a factor
- Tolerable delays with open fittings (Stone et al, 2008)
  - As low as 5-6 msec
  - Hearing threshold and direct-to-amplified path ratio are factors
- Common practice: limit overall delay to 10 msec
- Limits constrain signal processing capabilities:
  - Number of frequency bands or bins
  - Signal processing (beamforming, noise reduction)
  - Binaural processing (beamformer)
  - Remote microphone communication

Methods

Research Questions:

When comparing hearing-aid throughput delays of 4.5, 10, 15 and 20 msec in background noise levels greater than 70 dB SPL:

1. Are normally hearing listeners able to detect differences between the delays?
2. Do normally hearing listeners find the delays acceptable?

Participants:

Ten normally hearing listeners compared processing delays ranging from 4.5 to 20 msec under conditions where the background noise level was 70 dB SPL or greater

Hearing Aid Devices:

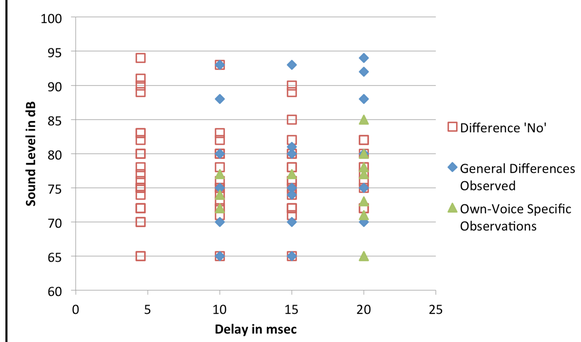
- Starkey Xino RIC devices with firmware that allows throughput delay to be parameterized.
- Receivers were fit with non-occluding earbuds.
- Gain prescription was best-fit with Starkey eStat for a 30-dB flat hearing loss.
- Four memories were programmed identically except for throughput delay:
  - Memory 1 contained the standard 4.5 msec delay
  - Memories 2-3 contained randomized delays of 10, 15 and 20 msec.

Procedure:

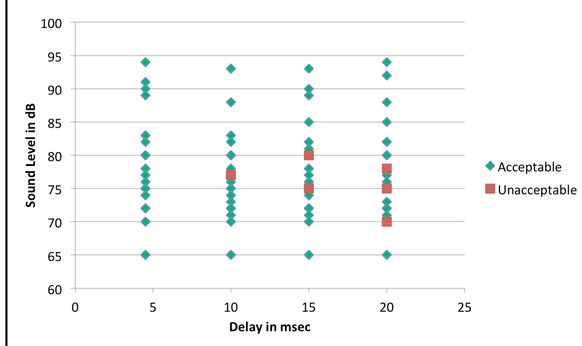
- Participants listened to Memory 1 (4.5 msec delay) in all normal/*quiet* listening conditions.
- Participants sought out noisy situations (crowds, restaurants, malls, etc.).
- Noise level was assessed using a calibrated sound meter app on a hand-held device.
- Participants compared Memories 2-4 to Memory 1 in noisy situations while listening to environmental sounds, speech of others and their own voice.
- Participants logged perceived differences and acceptability of each memory in each listening situation.

Results

- Ten participants reported on 104 listening trials.
- Background noise levels ranged from 65-95 dB SPL.



- Four of ten participants perceived no difference across all delays.
- General differences were observed in 33/104 trials (6/10 participants) for delays ≥ 10 msec:
  - 9(4) @ 10 msec; 9(5) @ 15 msec; 15(5) @ 20 msec
- Qualitative reports of sound quality included descriptions of phasing, reverb, echo, "sretched-out".
- Own-voice differences were observed in 12/104 trials (5/10 participants) for delays ≥ 10 msec:
  - 3(2) @ 10 msec; 1(1) @ 15 msec; 8(4) @ 20 msec



- Nine of ten participants reported all latencies as acceptable in at least one trial.
- All latencies were reported as acceptable at noise levels > 80 dB SPL.
- Unnacceptable delays were reported in 6/104 trials (3/10 participants):
  - 1(1) @ 10 msec; 2(1) @ 15 msec; 3(2) @ 20 msec;

Discussion

Other factors affected by delay:

- Audio-visual asynchrony
  - Lip-readers tolerate up to ~40 msec delay.
- Tactile-acoustic interaction
  - Impulsive sounds from cutlery, keyboards, etc. are impacted by hearing-aid throughput delay.

Laboratory control vs real-world conditions:

- Difficult to control for sound level in real-world environment.
- Difficult to recreate true noise environment and communication scenarios in laboratory environment.

Other factors may affect perception and acceptance of throughput delay:

- Hearing impairment
- Acceptance of a particular delay may depend on conditions of improved speech intelligibility.

Summary

- Our data suggests that listeners can tolerate longer than established hearing-aid processing delays under noisy listening conditions.
- Some listeners could detect differences in throughput delay but most found delays up to our maximum-tested 20 msec to be acceptable in noise.
- Future work will examine the effect of hearing impairment and trade-offs with SNR improvements.

References

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.

Cole, B. (2005). *Group Delay and Processing Delay in Hearing Aids: The Facts and the Fantasies. Audio Note 3*.

Kates, J. M. (2005). Principles of Digital Dynamic-Range Compression. *Trends in Amplification*, *9*(2), 45–76.

Stone, M. A., & Moore, B. C. (1999). Tolerable hearing aid delays. I. Estimation of limits imposed by the auditory path alone using simulated hearing losses. *Ear and Hearing*, *20*(3), 182–192.

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.

Stone, M. A., & Moore, B. C. J. (2003). Tolerable hearing aid delays. III. Effects on speech production and perception of across-frequency variation in delay. *Ear and Hearing*, *24*(2), 175–183.

Stone, M. A., & Moore, B. C. J. (2005). Tolerable hearing-aid delays: IV. effects on subjective disturbance during speech production by hearing-impaired subjects. *Ear and Hearing*, *26*(2), 225–235.

Stone, M. A., Moore, B. C. J., Meisenbacher, K., & Derleth, R. P. (2008). Tolerable Hearing Aid Delays. V. Estimation of Limits for Open Canal Fittings. *Ear and Hearing*, *29*(4), 601–617.

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/

Zakis, J. A., Fulton, B., & Steele, B. R. (2012). Preferred delay and phase-frequency response of open-canal hearing aids with music at low insertion gain. *International Journal of Audiology*, *51*(12), 906–913.

Acknowledgments

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