



# Sound Quality Comparison of Streamed Audio Through MFi-Compatible Acoustic Aids and a Contact Hearing Aid

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Suzanne Levy, Ph.D.

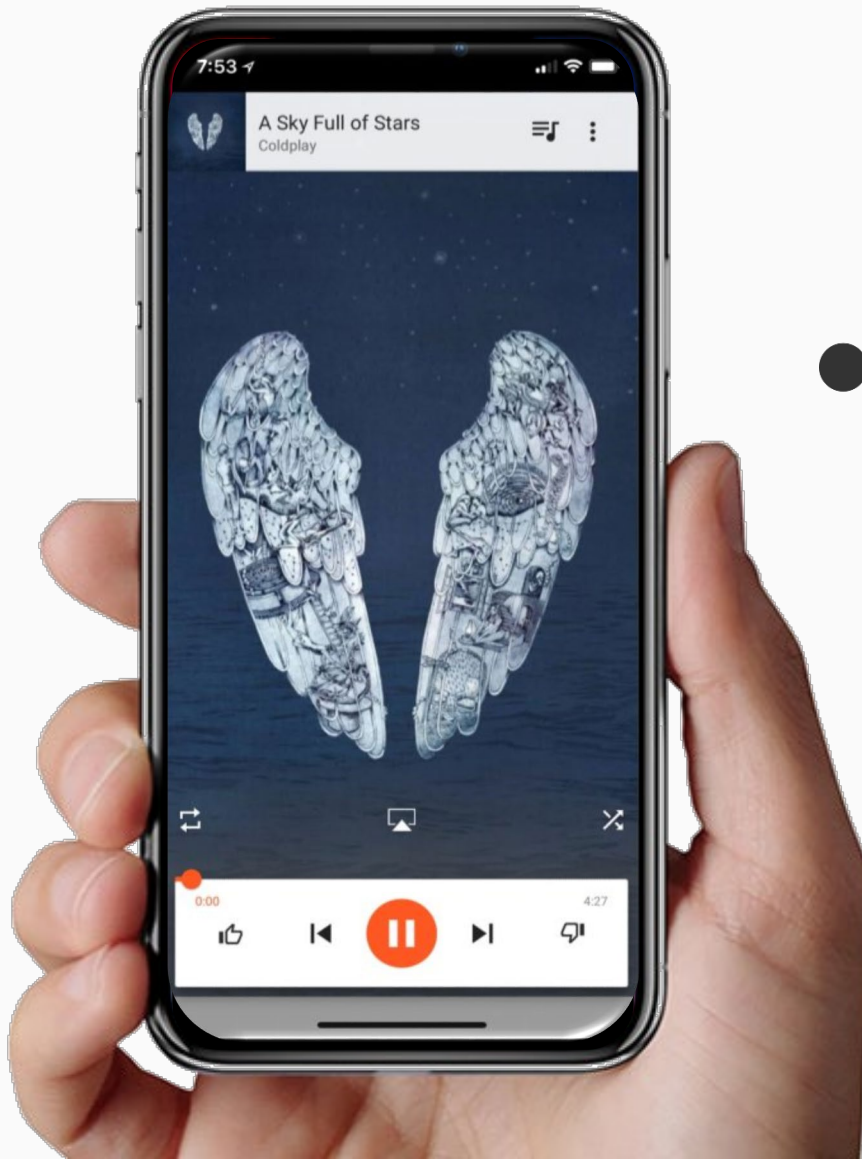
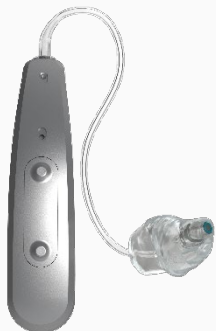
Contributors: Timothy Streeter; Madeline Huberth, Ph.D.; Drew Dundas, Ph.D.; Kelly Fitz, Ph.D.  
Earlens Corporation, Menlo Park, CA

# Disclosures

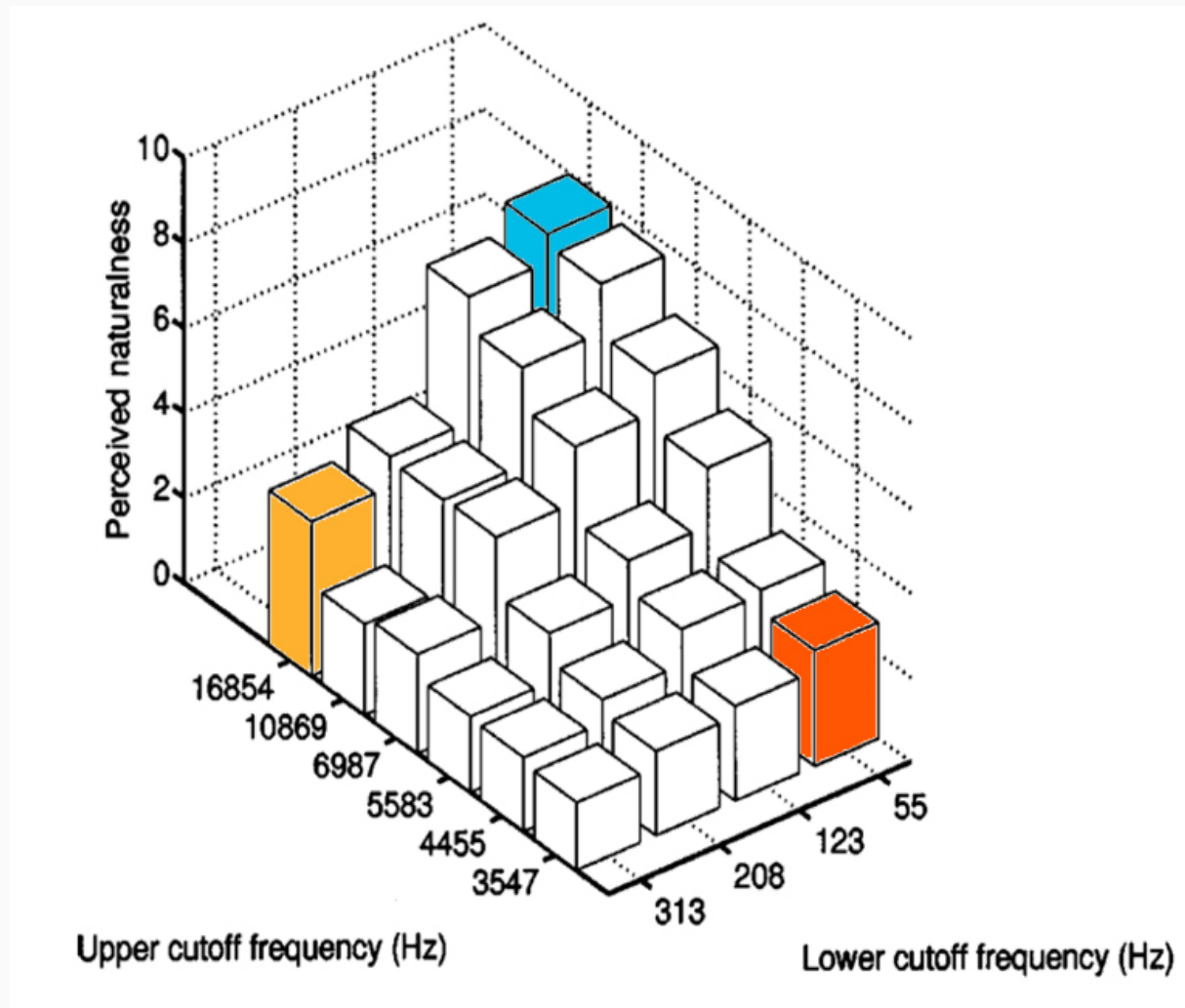
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- Employed at Earlens Corporation

Made for  
Apple iPhone | iPad | iPod



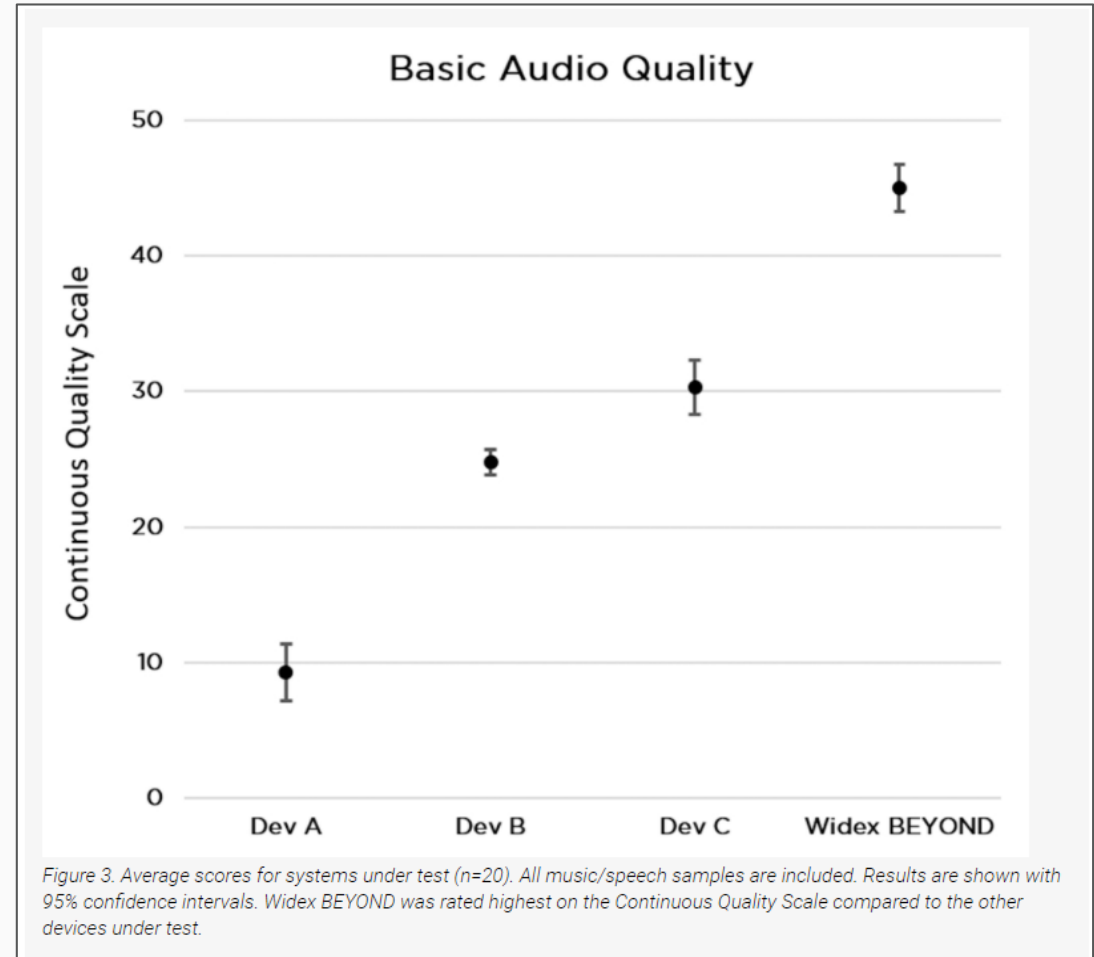
# What we know-Bandwidth affects sound quality



**Broad bandwidth =  
natural sound quality**

# What we know—streaming sound quality in Acoustic Hearing Aids (AHA)

Varies widely between devices from different manufacturers



# What we know--Streaming Sound Quality in ACAs

Widex streaming audio quality rated superior to other 2.4GHz MFi hearing aids for a closed (fully occluded) fitting



Figure 5. Average scores for systems under test for music (left) and speech (right) samples (n=20). Results are shown with 95% confidence intervals.

# Limitations

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- Normal hearing listeners
- Closed/Occluded fittings were used
- Limited bandwidth of acoustic hearing aids
  - Limits high frequency audibility

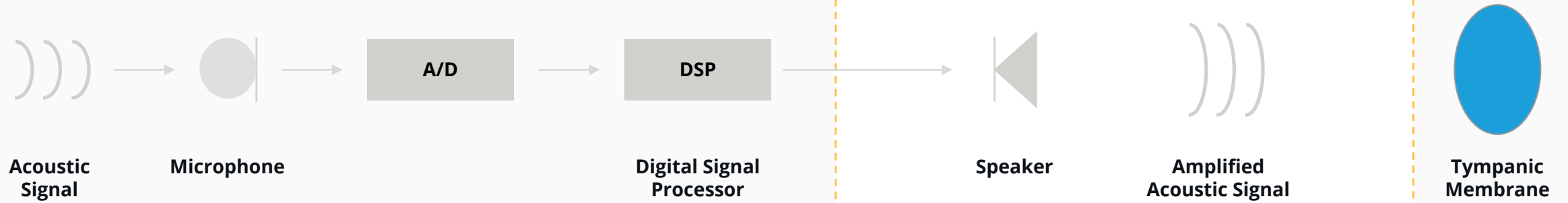
# The Earlens Contact Hearing Aid (CHA)

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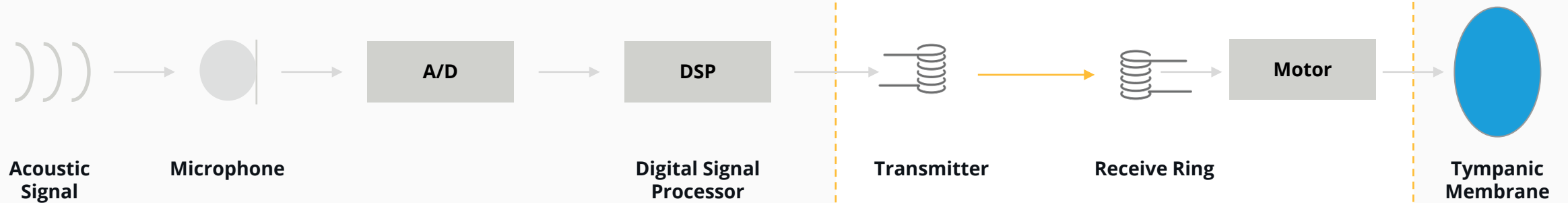


# What is the Earlens CHA?

## Air-Conduction Hearing Aid



## Earlens Contact Hearing Solution



# The Full Spectrum of Sound



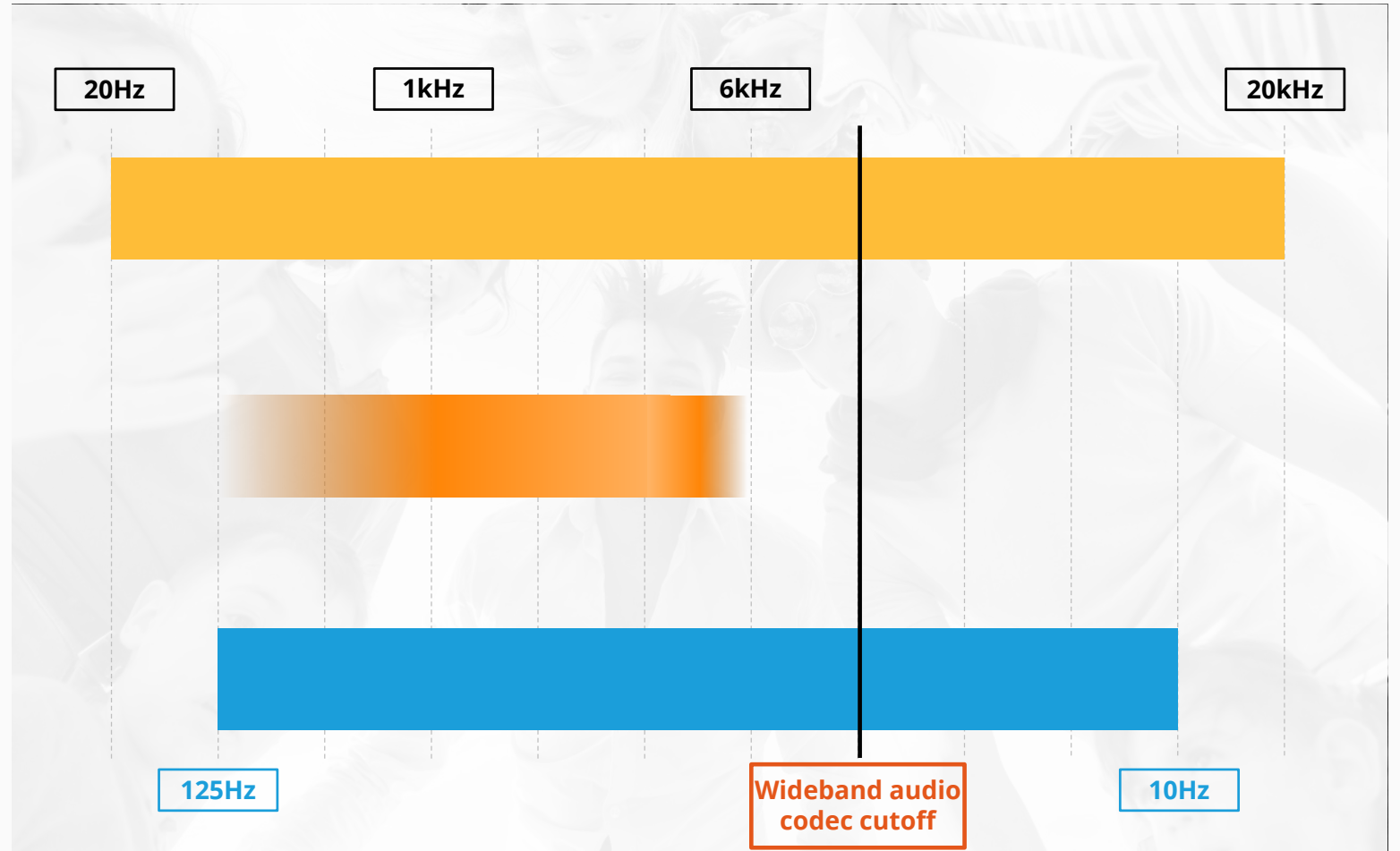
**Perfect  
Hearing**



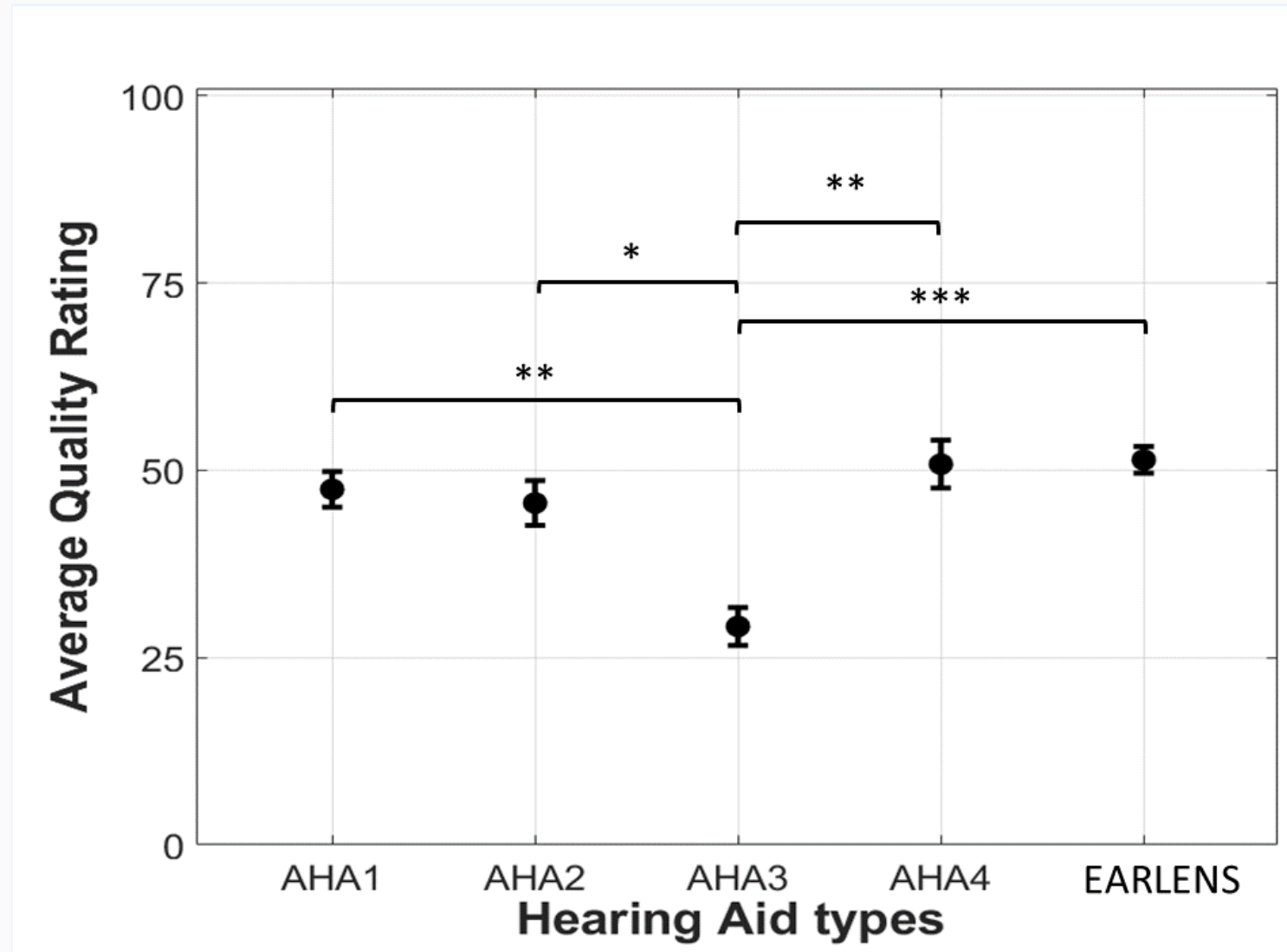
**Acoustic  
Hearing Aid**



**Contact Hearing  
Aid**



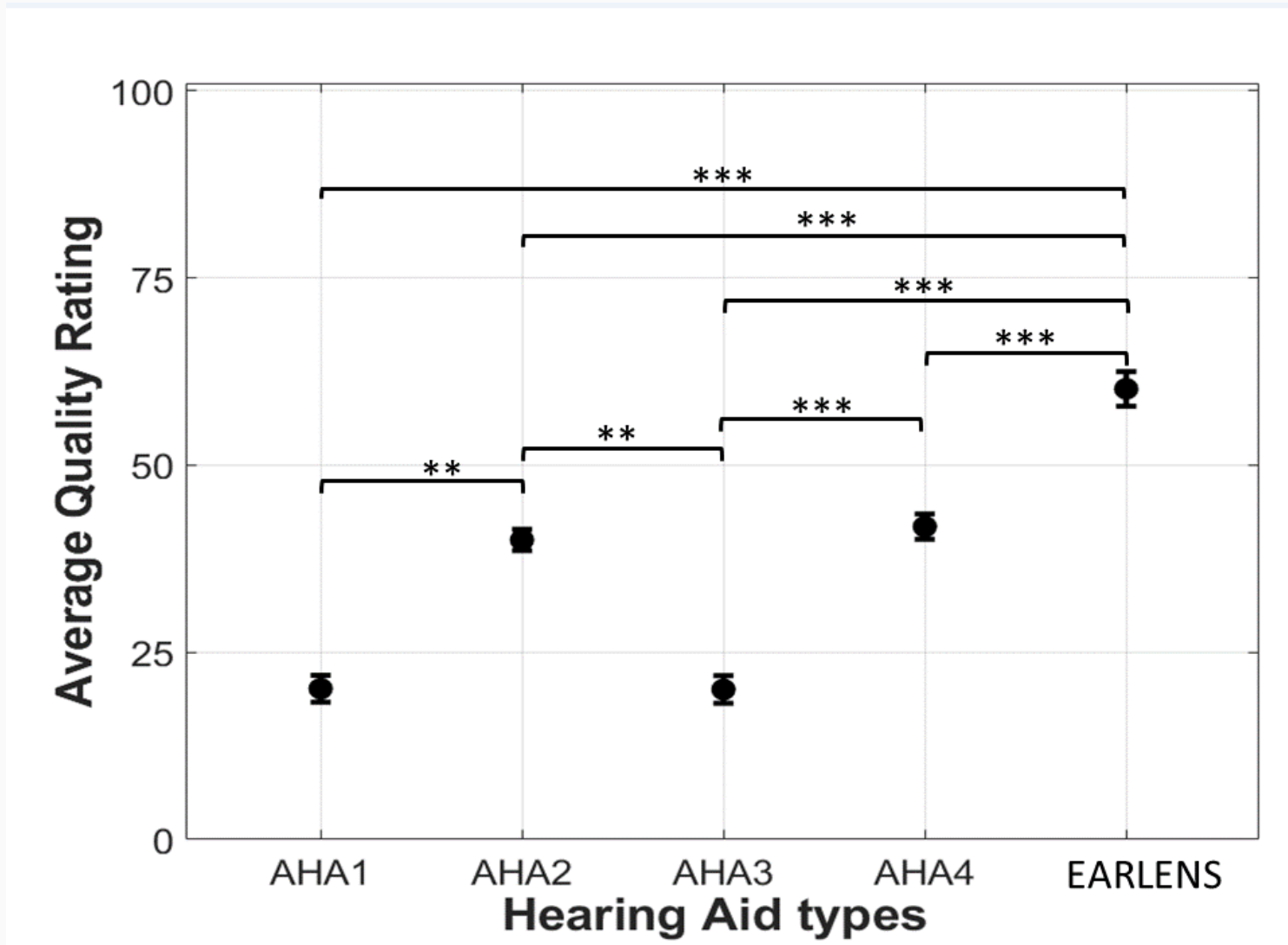
# Closed Fitting - All Stimuli



\*\*\*  $p < .001$ , \*\*  $p < .01$ , \*  $p < .05$

Standard error bars

# Open Fitting - All Stimuli



\*\*\*  $p < .001$ , \*\*  $p < .01$ , \*  $p < .05$

Standard error bars

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What about the streaming sound quality ratings of individuals with hearing loss?

# Aim

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- Evaluate streamed audio sound quality subjectively
  - In a population with hearing impairment
  - With open and closed venting
  - With AHAs and a broader bandwidth contact hearing aid

# Methods



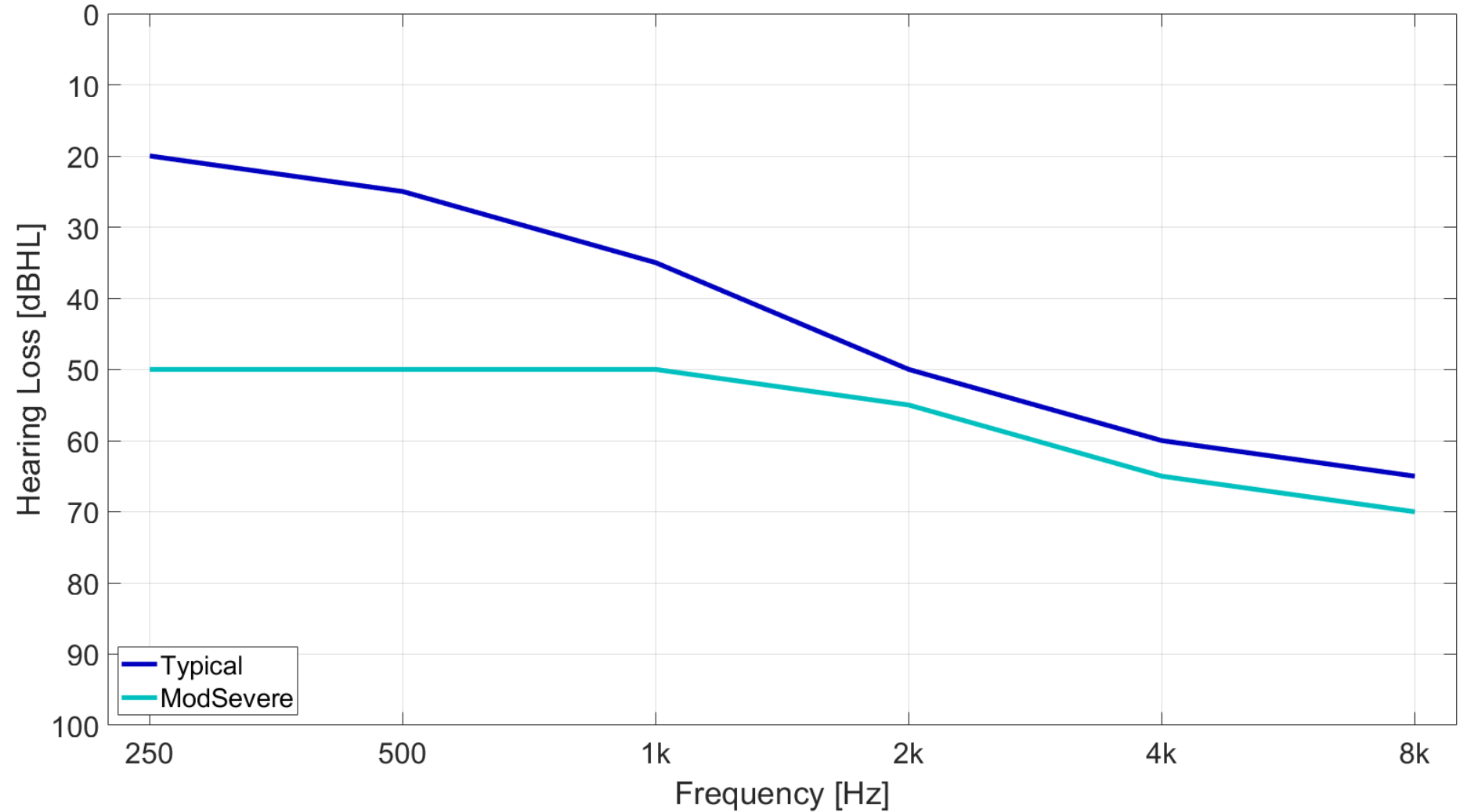
# Participants

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- Symmetric hearing loss
- Hearing loss falls within 15 dB of all but one frequency for at least one of the pre-determined hearing loss profiles from Bisgaard et al. (2010)
- 24 participants; 9 females and 15 males
- Listeners were paid for participation



# Hearing Loss Profiles



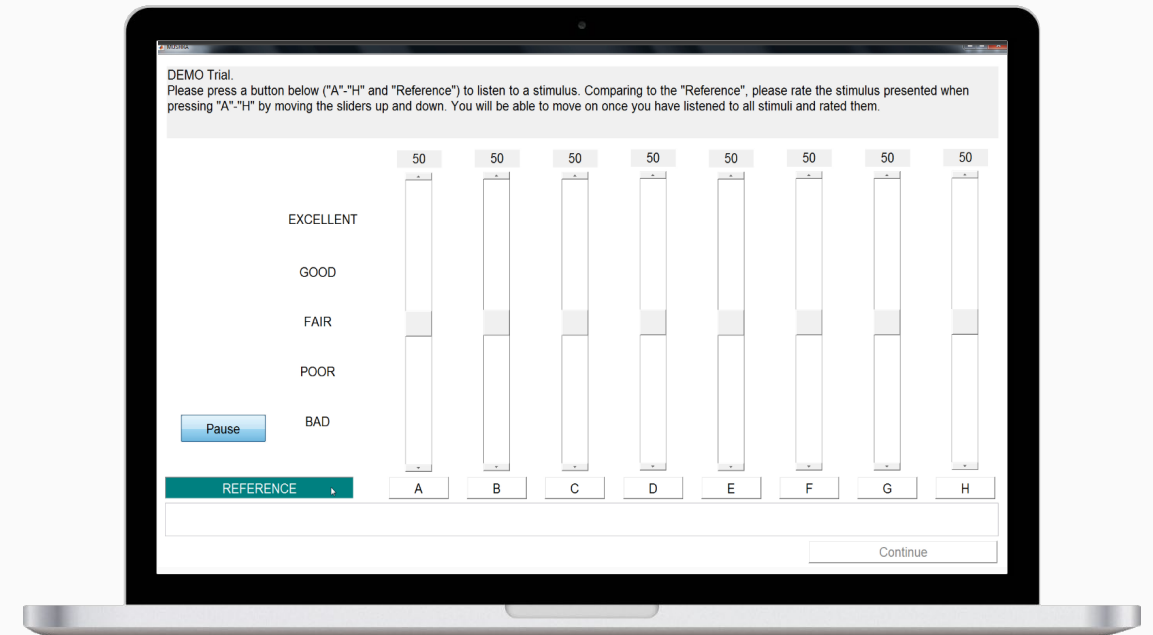
# MUSHRA Procedure

- **M**U**L**t**i** **S**t**i**m**u**l**u**s test with **H**idden **R**eference and **A**nchor
- Assess sound quality in standardization organizations, academia, and the hearing industry
- Rate audio quality by comparing unlabeled stimuli to a reference “ideal”

Unlabeled Stimuli*
Anchor 1- LP filtered 4k Hz
Anchor 2- BP filtered 1k-4k Hz
Hidden reference
HA 'A'
HA 'B'
HA 'C'
HA 'D'
Earlens

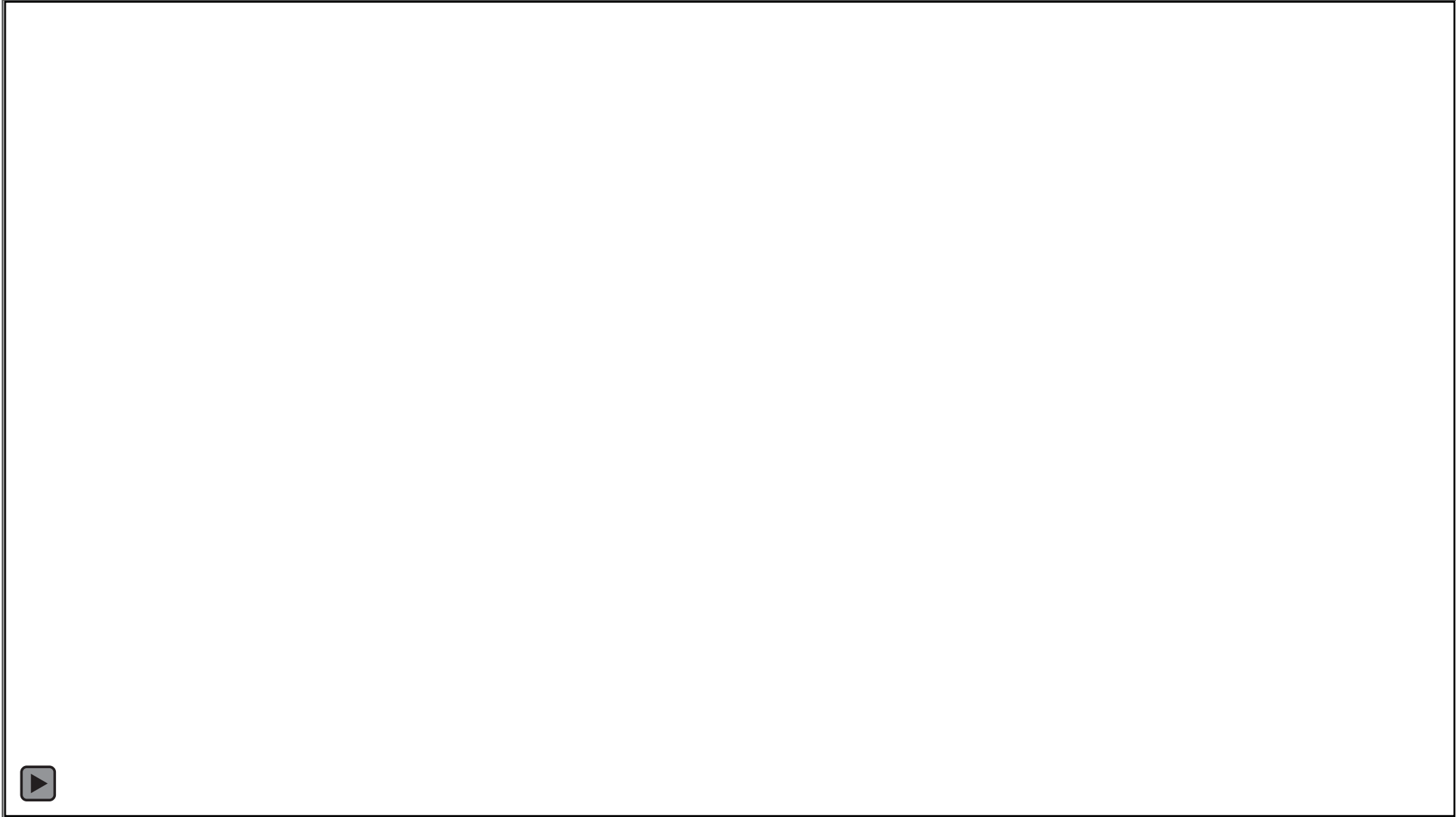
# MUSHRA Task

- Move freely between stimuli and reference
- Two blocks of 10 stimuli order counterbalanced
  - Open fit AHAs & Earlens
  - Closed fit AHAs & Earlens
- Speech, movie, and music sound samples



# MUSHRA Example

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# AHA Recorded Stimuli from 4 Premium Devices

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- Programmed for 2 different hearing loss configurations
  - Manufacturer default settings
  - Hearing aid mics muted
- Open and closed configuration
  - Apple iPod Touch



Example setup for open-dome AHA recordings worn by a KEMAR dummy head.

# Earlens Recorded Stimuli

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- Closest representation of hearing without actually having a Lens placed



Earlens Simulator



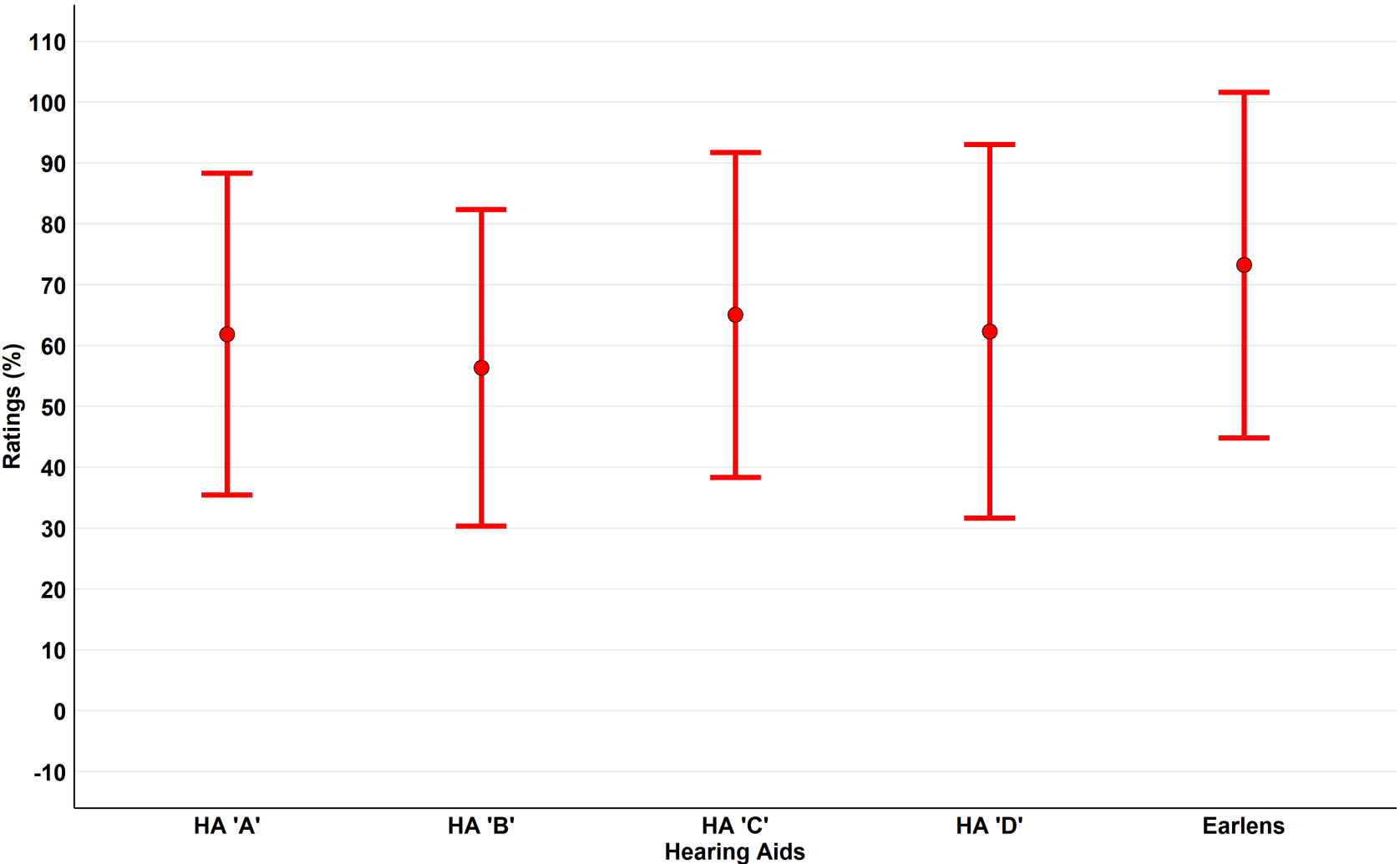
Earlens recording setup

# Results



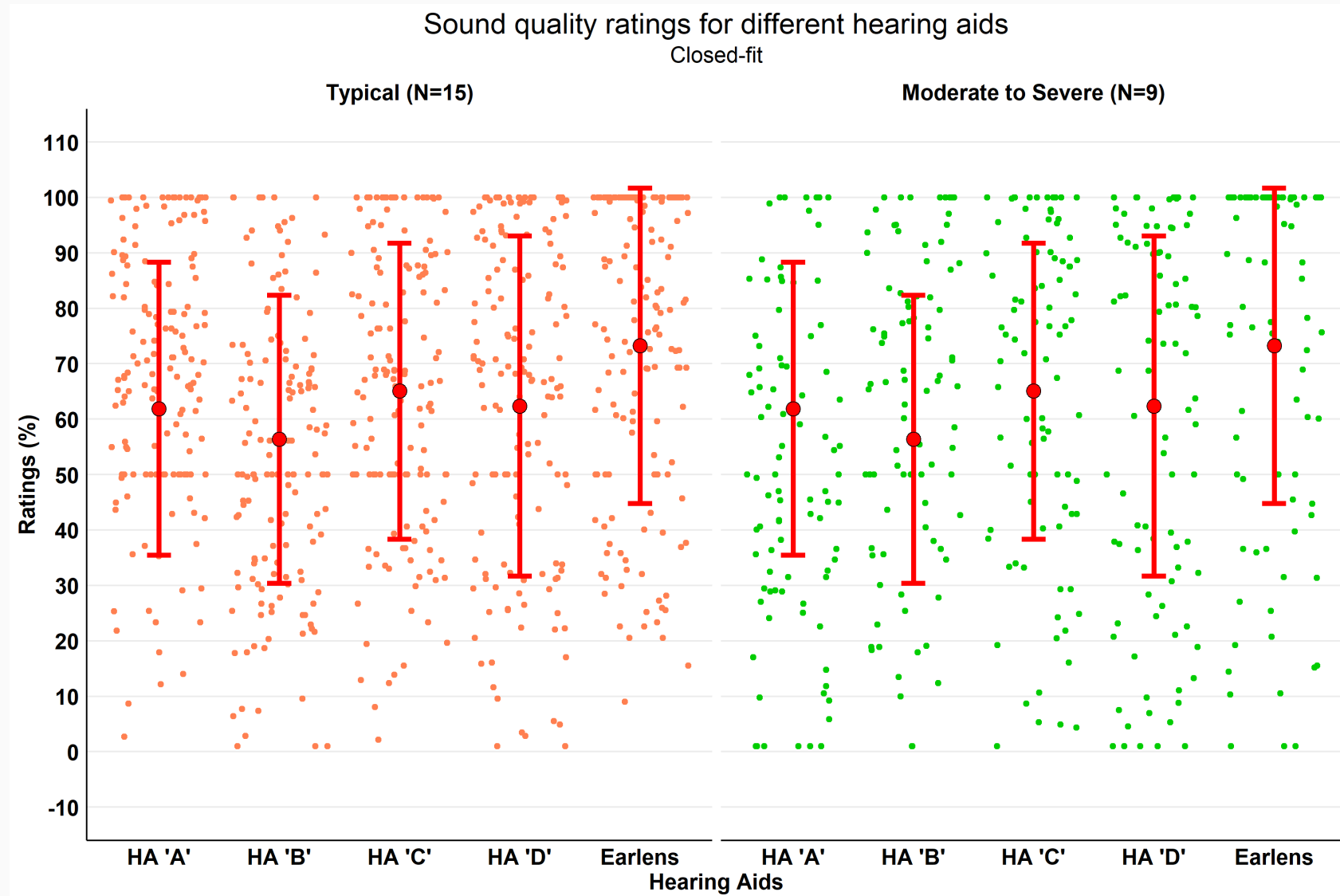
# Let's take a look at the scores-Closed Condition

Sound quality ratings for different hearing aids  
Closed-fit



$F(4, 1195) = 11.87, p < 0.00001$

# Let's take a look at the scores-Closed Condition



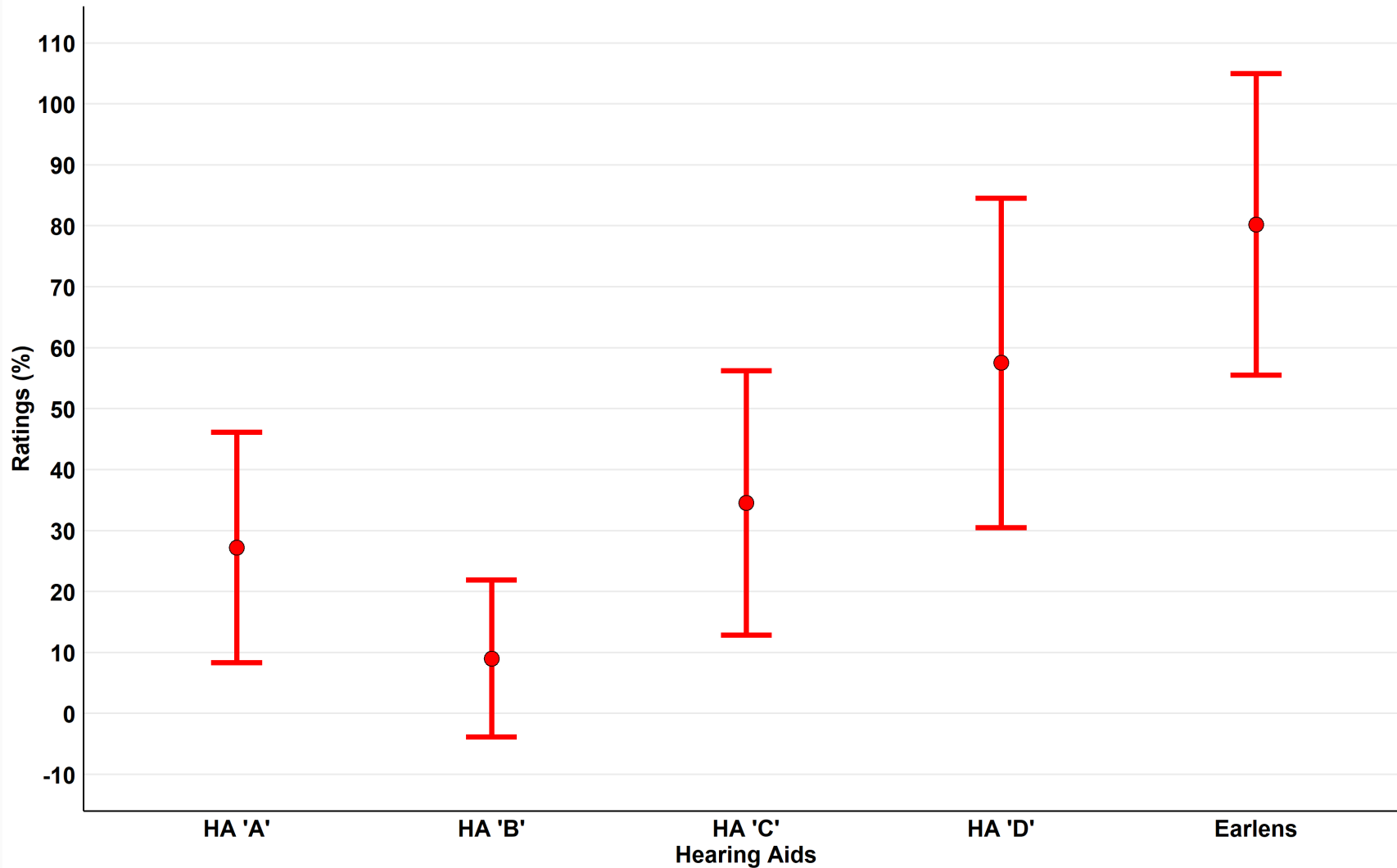
# Pairwise t-test with Bonferroni correction: Closed fit condition

Hearing Aids	HA 'A'	HA 'B'	HA 'C'	HA 'D'
HA 'B'	NS	-	-	-
HA 'C'	NS	**	-	-
HA 'D'	NS	NS	NS	-
Earlens	***	***	*	**

Note: \*\*\*  $p < 0.0000001$  ; \*\*  $p < 0.01$ , \*  $p < 0.05$

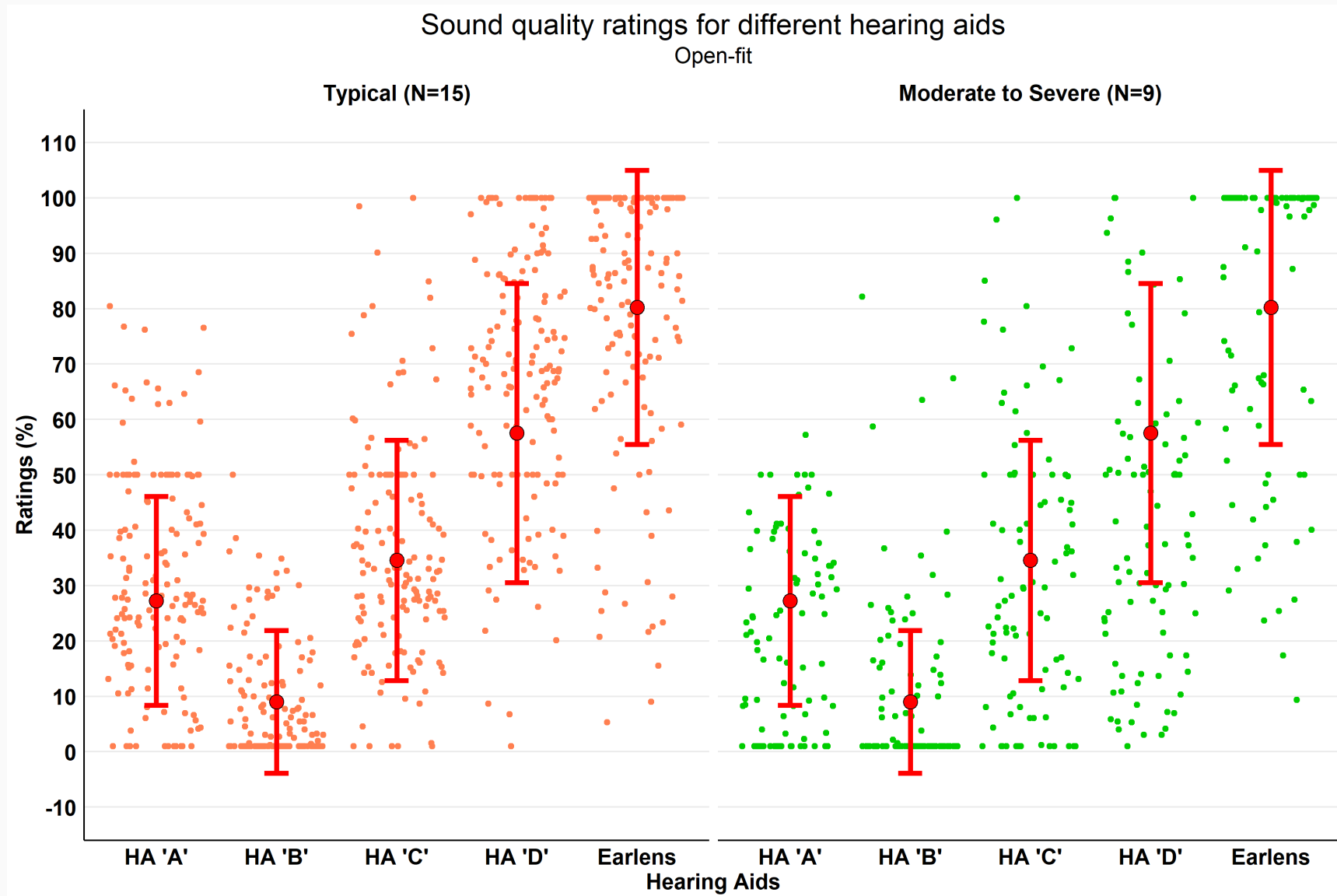
# Let's take a look at the scores-Open Condition

Sound quality ratings for different hearing aids  
Open-fit



$F(4, 1195) = 393.6, p < 0.0000001$

# Let's take a look at the scores-Open Condition



# Pairwise t-test with Bonferroni correction: Open condition

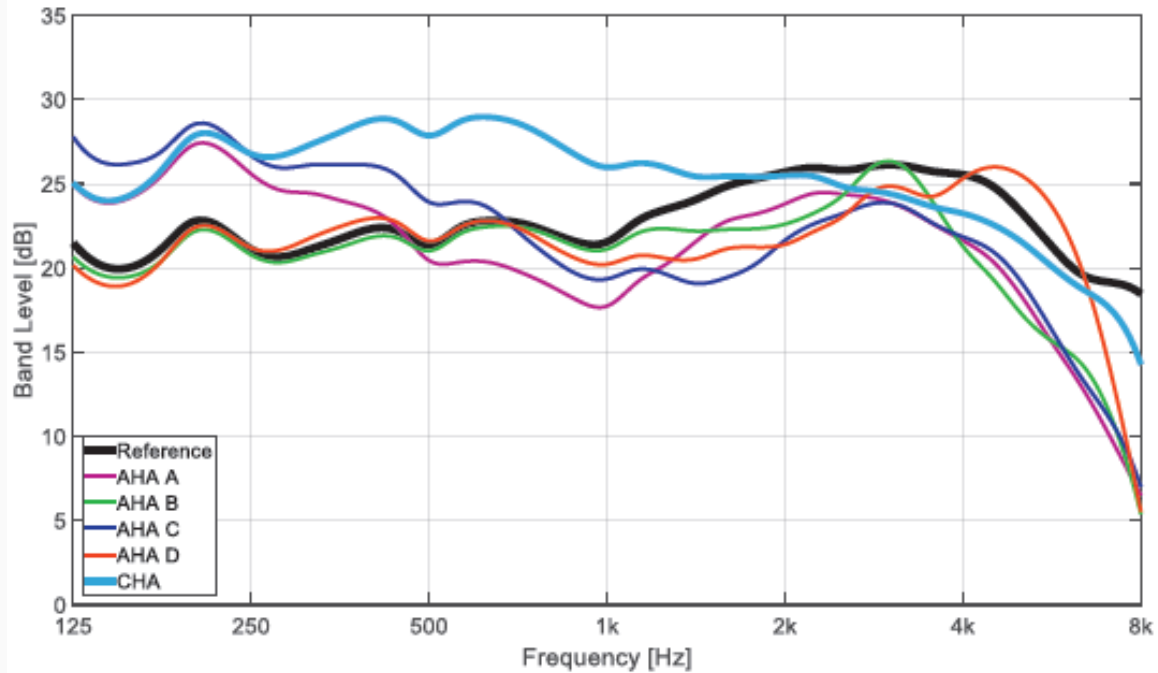
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Hearing Aids	HA 'A'	HA 'B'	HA 'C'	HA 'D'
HA 'B'	***	-	-	-
HA 'C'	**	***	-	-
HA 'D'	***	***	***	-
Earlens	***	***	***	***

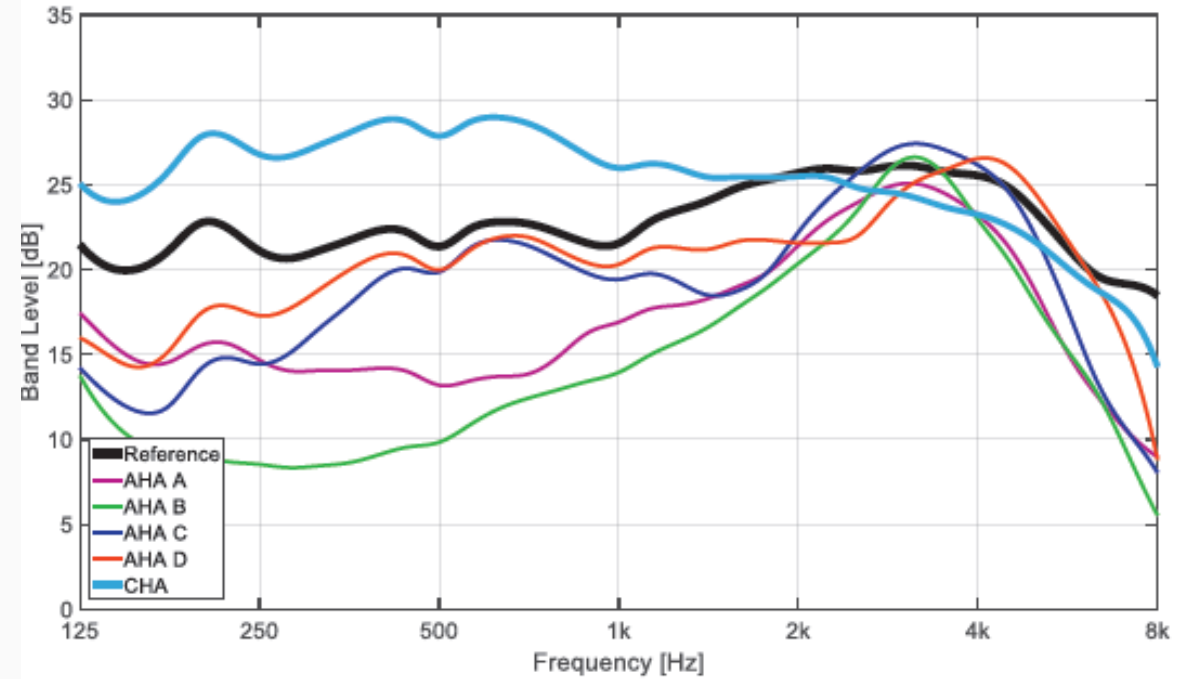
Note: \*\*\*  $p < 0.0000001$  ; \*\*  $p < 0.005$

# Long Term Spectral Averages

Average Stimulus Spectra for Closed Fittings



Average Stimulus Spectra for Open Fittings



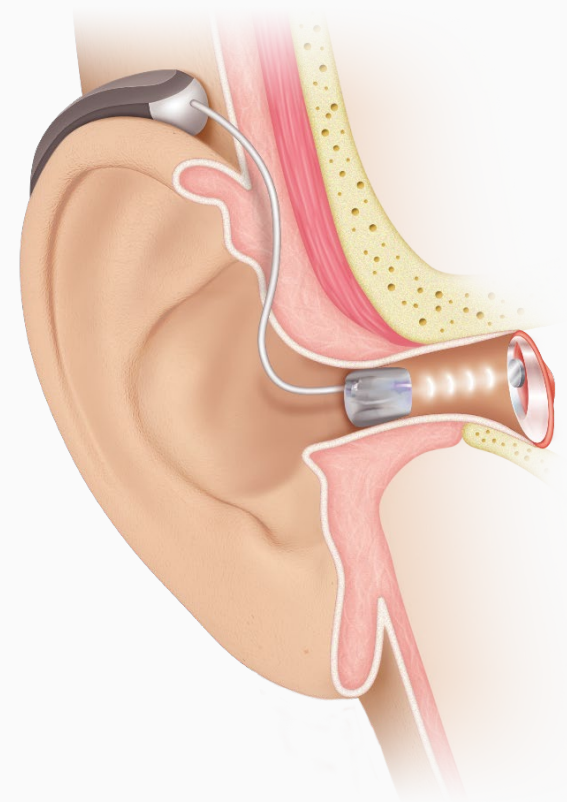
# Take-Home Messages



# Conclusions

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- The contact hearing aid was evaluated to have significantly higher sound quality than the AHAs in both the open and closed conditions.
- The most pronounced differences in audio quality ratings were observed in the block of open-fit devices.
  - Low-frequency output likely a key factor in subjective audio quality ratings.
- The contact hearing aid has been shown to be able to provide meaningful low and high frequency amplification while still maintaining a fitting that is similar to an open fit AHA.



# Areas of Future Study

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- Further exploration of acoustic features that explain variance in ratings.
- Extend this evaluation to non-streamed stimuli.



# Additional Earlens Presentations



## The "Magic" Revealed: What Is It That Makes the Sound Quality of Direct Drive Hearing Aids So Good?

**Drew Dundas, PhD, FAAA**

Friday, March 29th  
12:00pm – 12:30pm  
Room Union Station A



## Industry Update: Troubleshooting the Earlens Contact Hearing Aid

**Therese Velde, PhD**

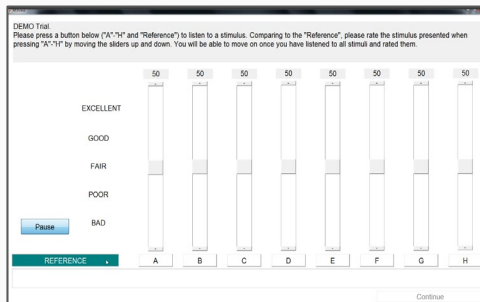
Friday, March 29th  
2:30pm – 3:00pm  
IU Room 2



## Comparison of a Light-Driven Contact Hearing Aid to an Inductive Contact Hearing Aid

**Suzanne Levy, PhD**

Friday, March 29th  
4:15pm – 4:45pm  
Room C160



Try MUSHRA @ Earlens Booth #309 in Exhibit Hall!

# References

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- Marston, D., & Mason, A. (2005). Cascaded audio coding. *EBU Technical Review*, (304), 1–9.
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