

Acoustic Transparency in Hearables – Technical and Perceptual Sound Quality Evaluation

Simon Doclo

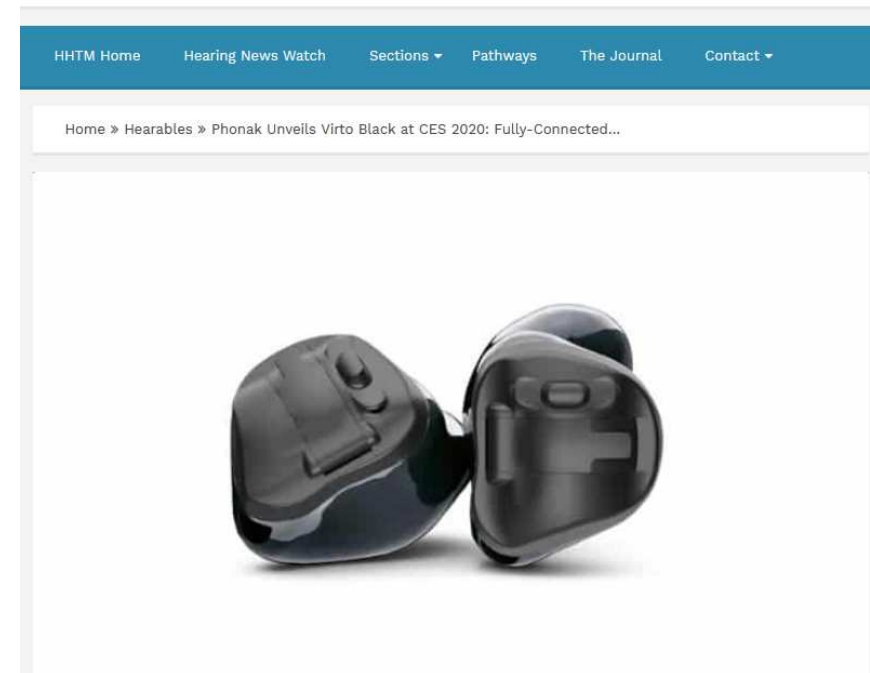
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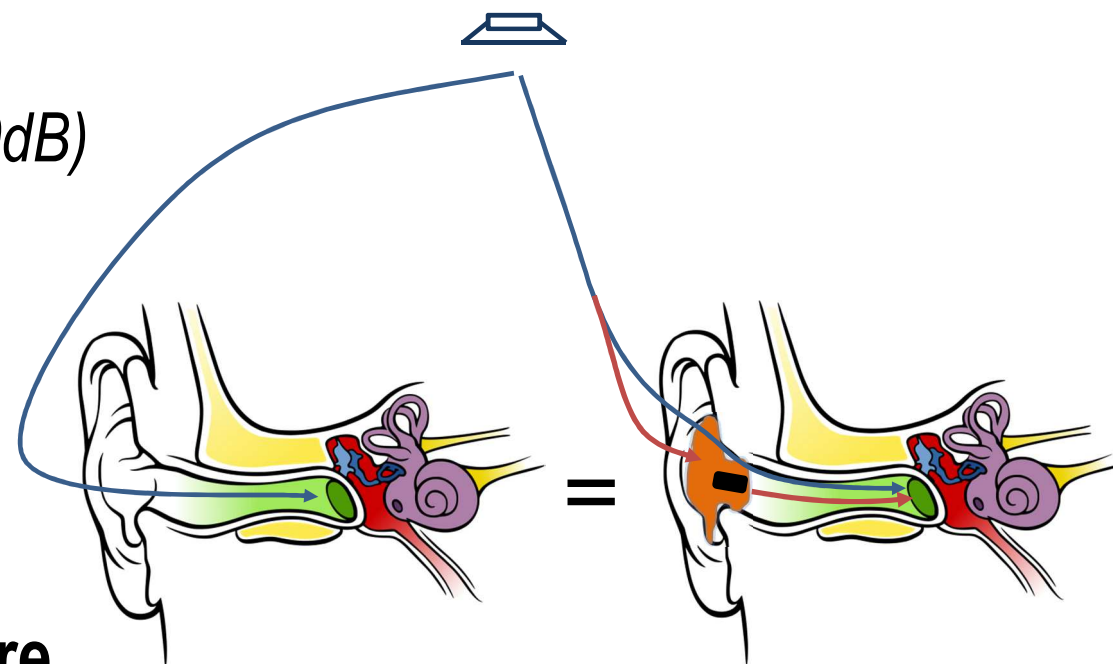
Hearing4all Symposium – Research Thread II

WearABLE HEARing technology

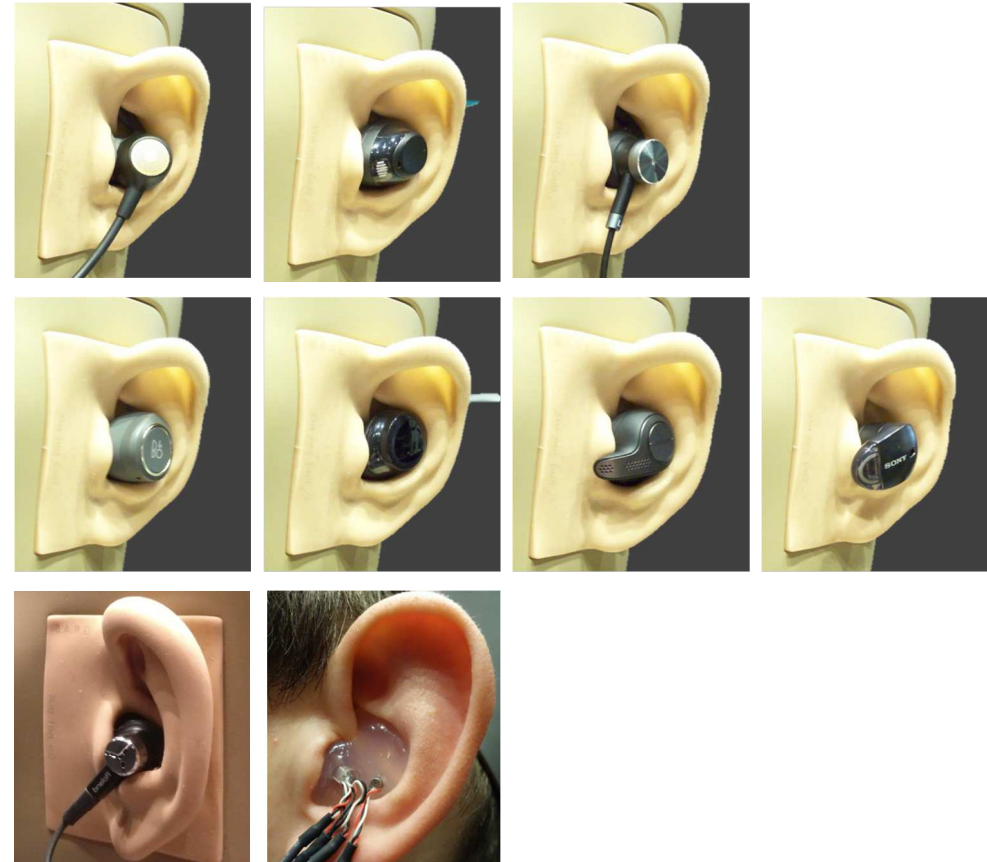
- More than earphone, no hearing aid
- Multiple Sensors, Functionalities, Applications



- Aim: **Acoustic transparency**
 - Hearing equivalent with open ear through hearing device ($REIG = 0dB$)
 - Naturalness, **Sound Quality**
 - Localization / Spatial hearing
- Basis for hearing support, mixed reality,...
- **Evaluation of hear-through feature**

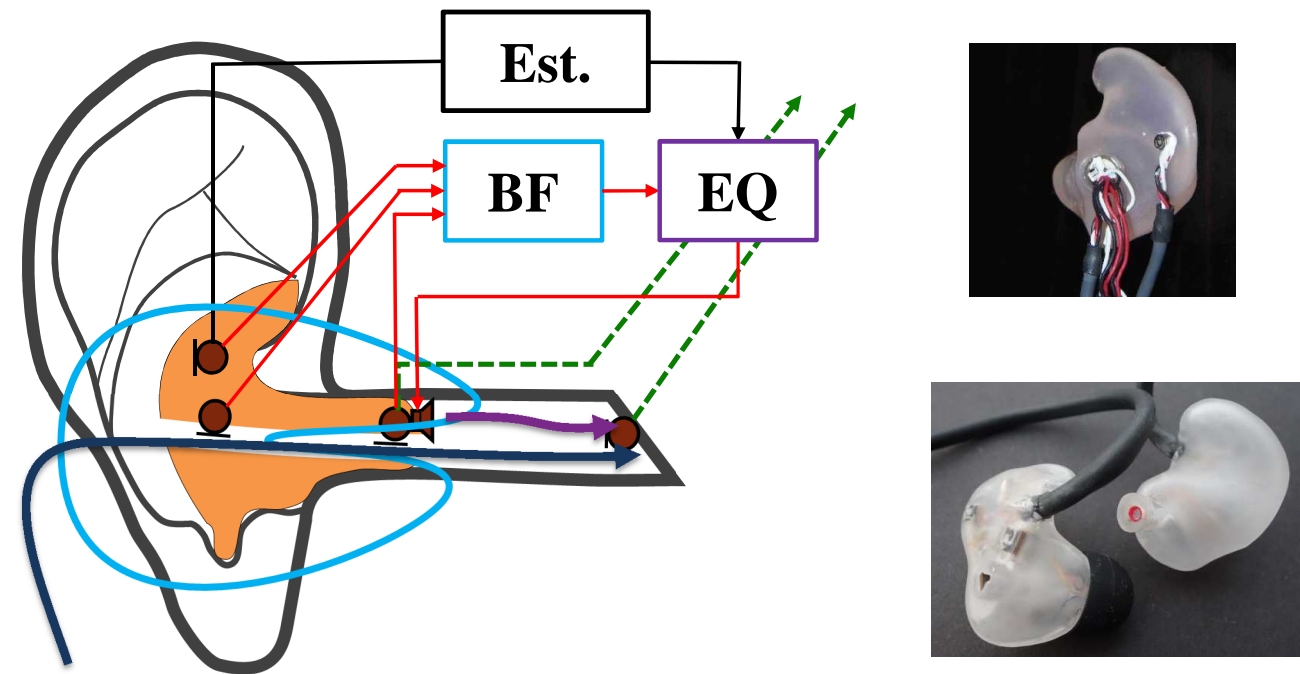


- 7 commercial hearables
 - 3 hearing support: **Devices A-C**
 - 4 wireless earbuds: **Devices D-G**
- 2 research prototypes
 - UOL Commodity: consumer hardware based hearing aid prototype
[Schädler 2017, Buhl, Denk et al. 2019]
 - UOL Acoustically Transparent Earpiece: Adaptation to individual ear acoustics
[Denk et al. 2018, Schepker, Denk et al. 2019]



Acoustically Transparent Earpiece (Hearpiece)

- Individualized In-Situ Calibration

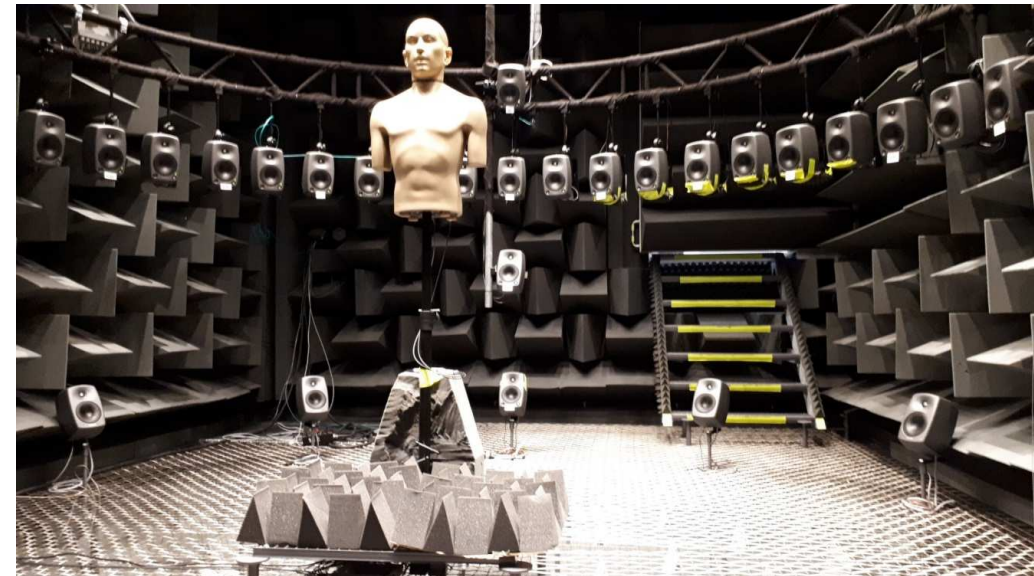


Commodity Device

- Generic Filters



- Anechoic chamber
- KEMAR with anthropometric ears
- Controlled Fit
- Transfer functions measured for 93 directions, overlapping exponential sweeps
- Measurements:
 - Open-ear responses
 - Occluded Responses (REOR)
 - Hear-through Responses (REAR)
 - Non-linearities, self-noise

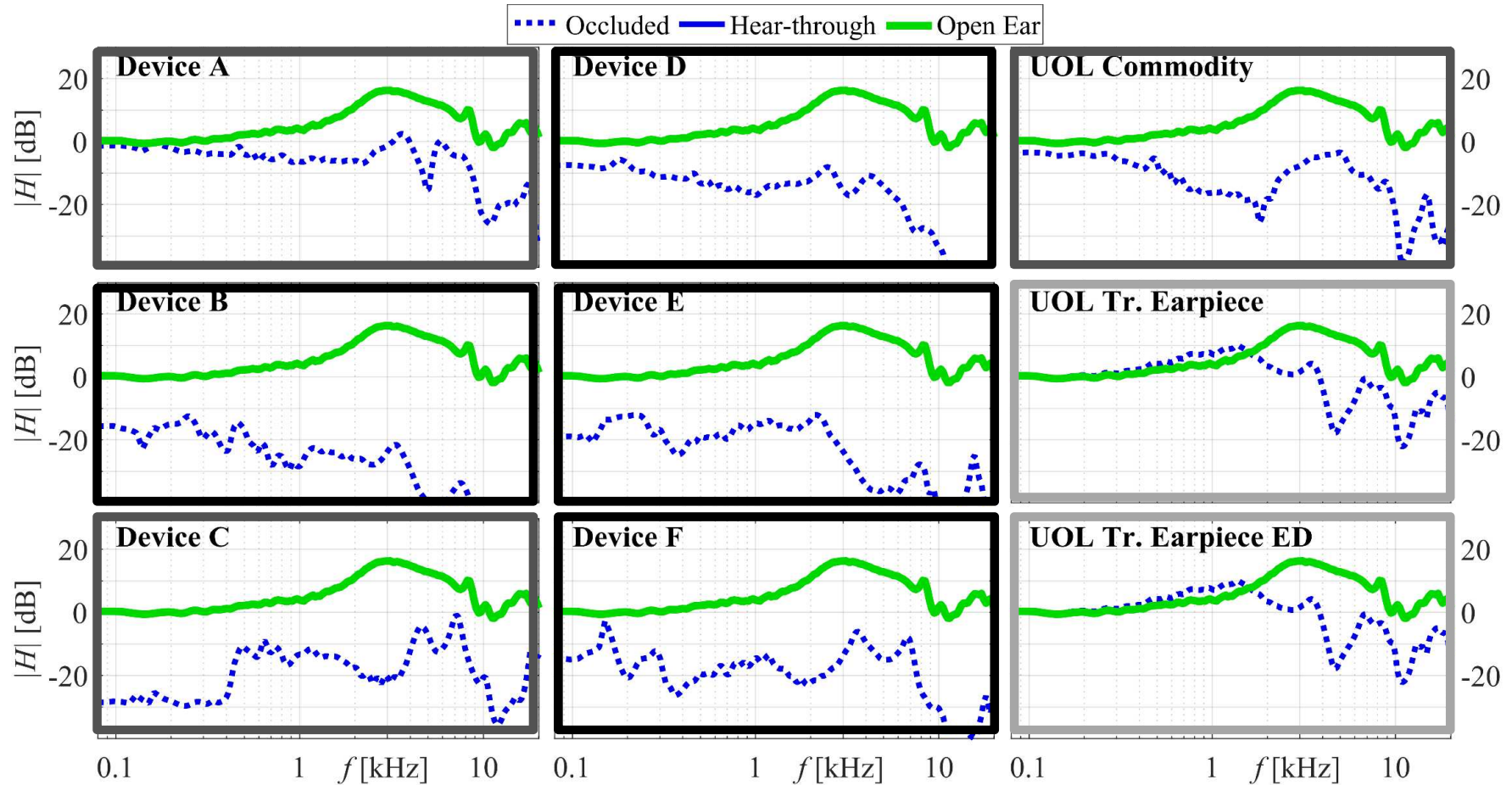


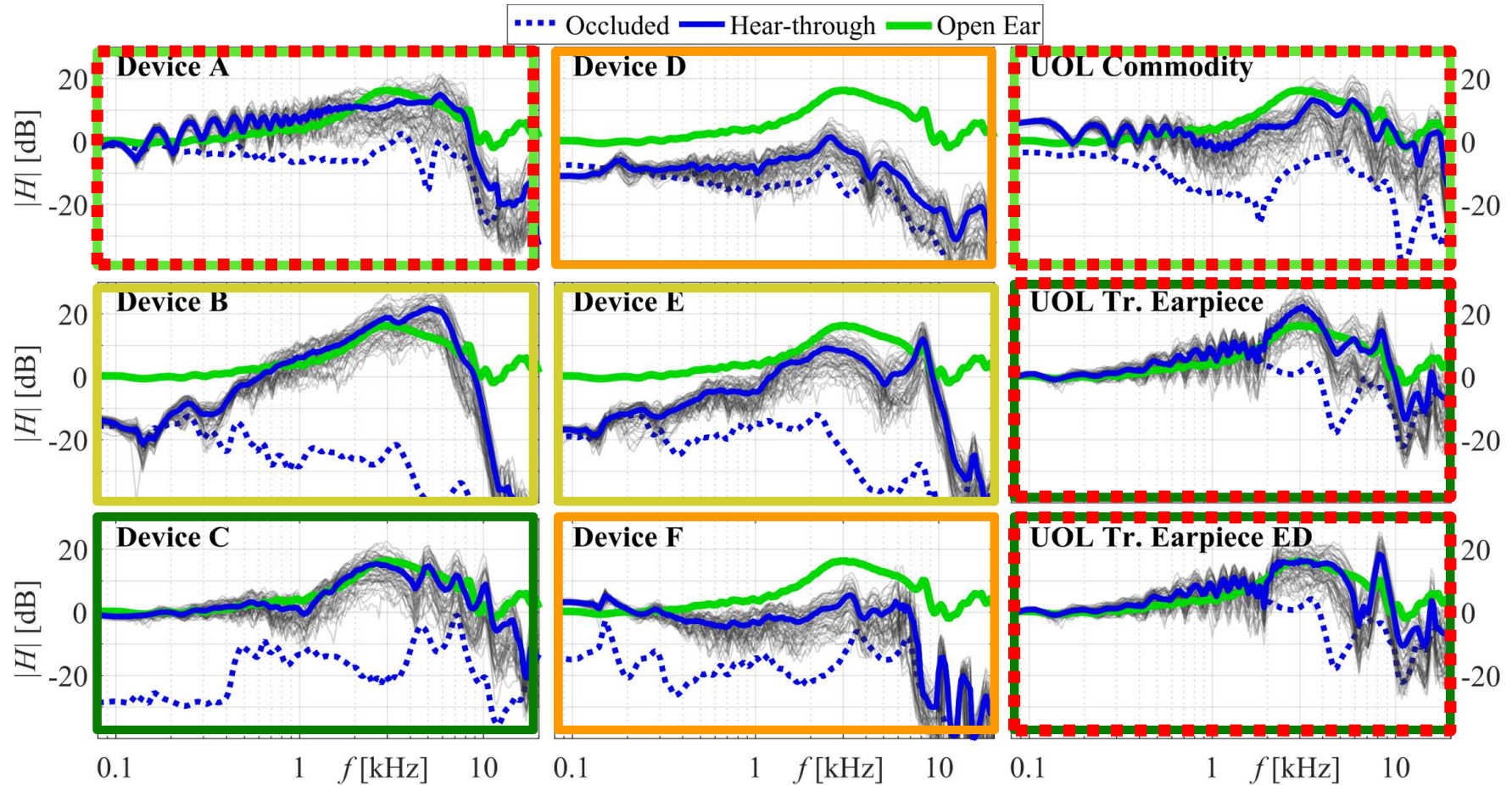
Technical Results: Frequency-Domain

Hearing Support

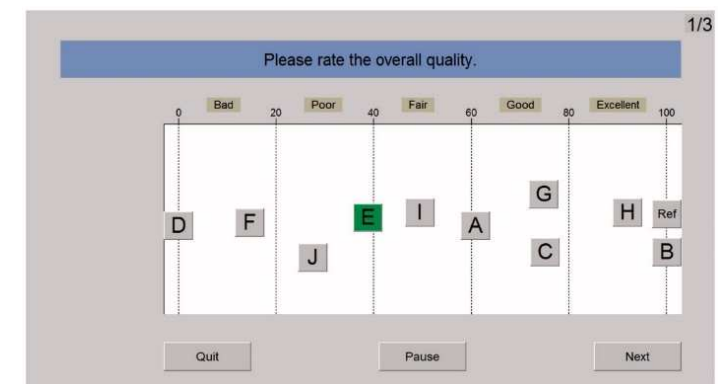
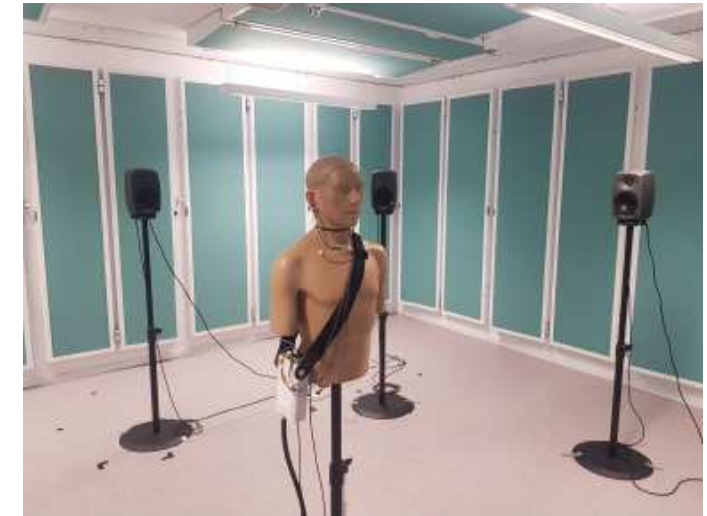
Earphones

Research Devices

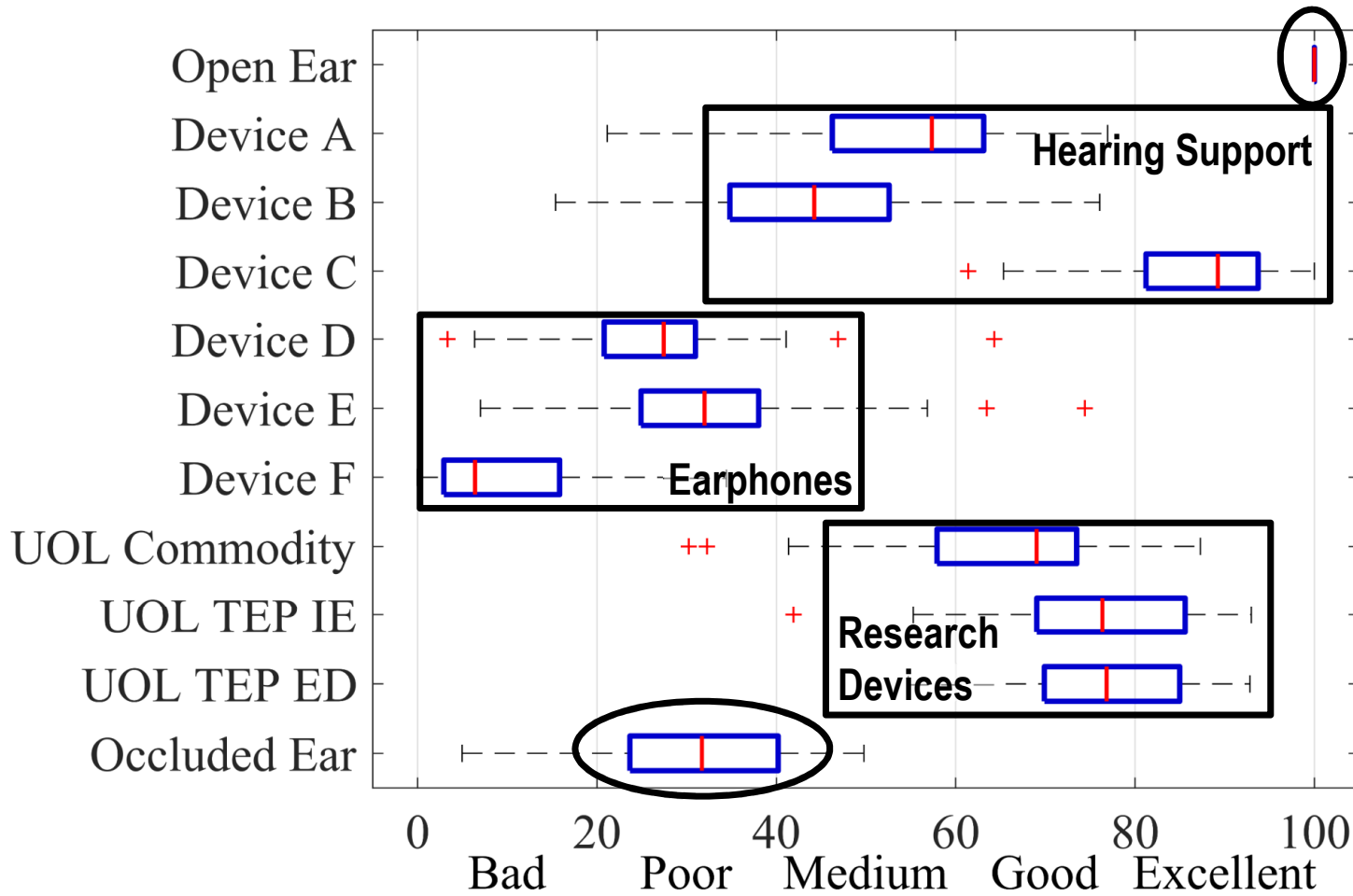




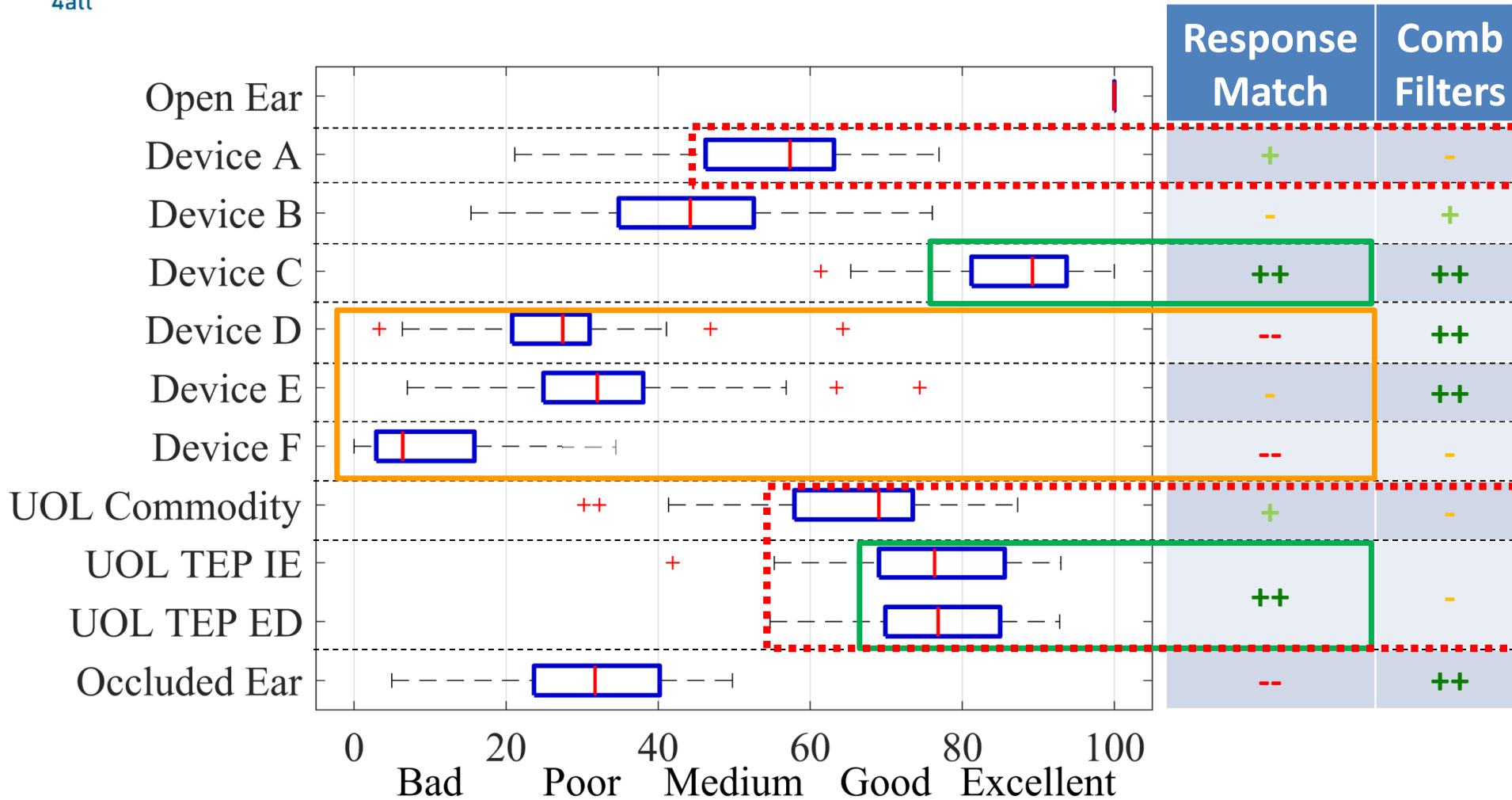
- **Stimuli:**
 - Pre-recorded signals (speech/music, 3 directions) using KEMAR wearing devices under test
 - Presented to subjects over Sennheiser HD650 headphones
- **Task:** Evaluate overall quality, MUSHRA Drag&Drop
 - Experiment 1: Comparison to open-ear reference
 - Experiment 2: Without reference
 - Anchor: Occluded ear
- **Subjects:** N=17 self-reported normal-hearing



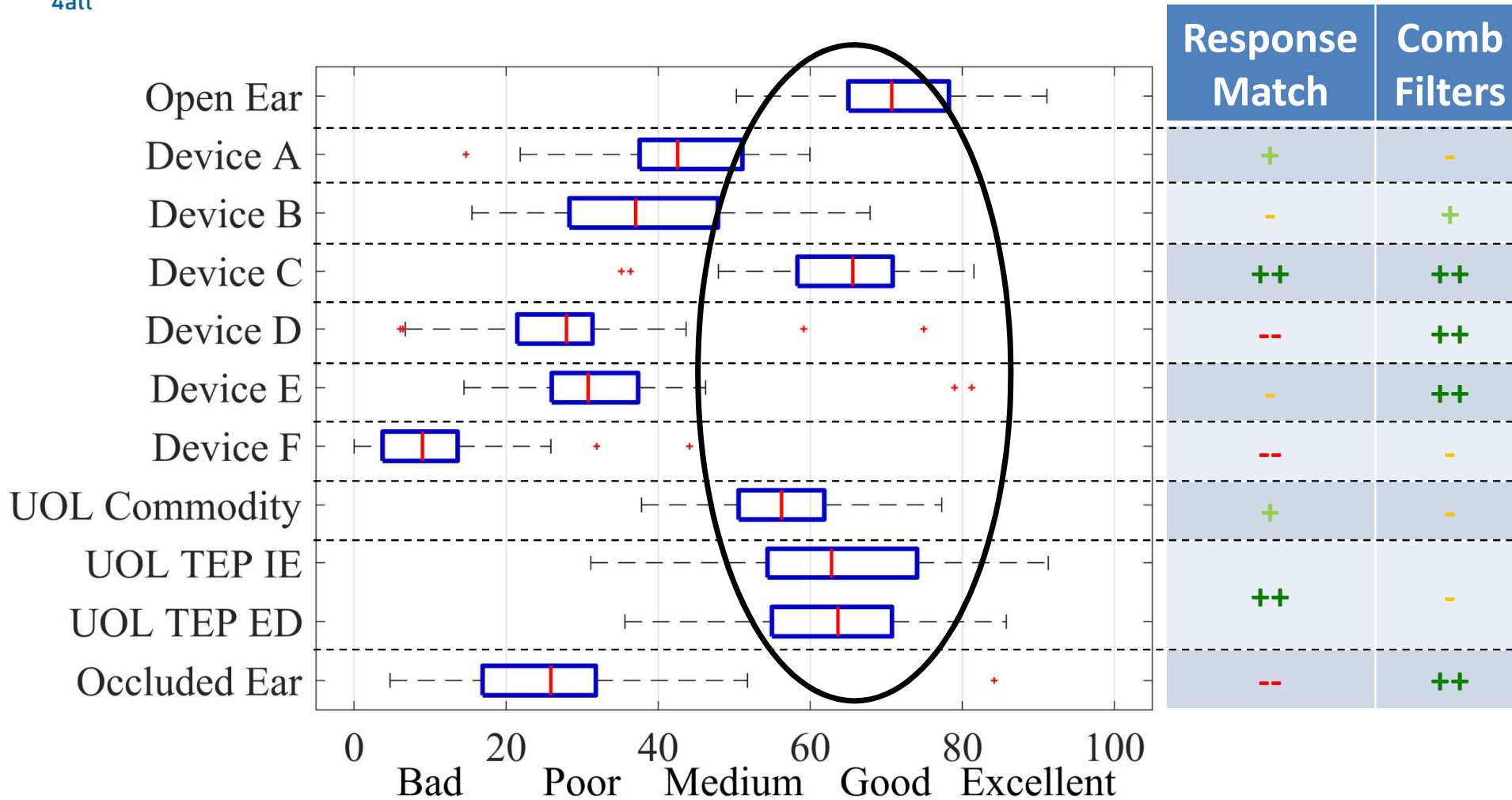
Subjective Results: Open-ear reference given



Subjective Results: Open-ear reference given



Subjective Results: *No reference given*



- Evaluated hear-through features of commercial and research hearables
- Large differences among commercial hearables
- **Open-ear transmission to be conserved for high sound quality**
 - Most important: Frequency response
 - Also: Avoid comb-filter effects, binaural distortions
- **UOL research prototypes** in par with best commercial devices
 - Next steps: exploit all available receivers and microphones for active noise and occlusion control + integrate individualized ear canal models

Thank you for your attention

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References

Denk, Schepker, Doclo, Kollmeier (2020): Acoustic Transparency in Hearables – Technical Evaluation, *J. Audio Eng. Soc.*

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