Reference Equivalent Threshold Levels for Two New Audiometric Transducers

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Introduction

We examined the performance of two new transducers, the Radioear B-81 bone vibrator, and the Radioear DD450 circumaural headphone. Thresholds from young, normal-hearing subjects were obtained with the two transducers. Thresholds obtained with the the B-81 bone vibrator (forehead placement) were compared with those obtained with the B-71 bone vibrator which has been in use for many years. Both devices have a circular contact area of 175 mm2 (+ 25 mm2) that meets the requirement of the audiometer standard (ANSI S3.6-2010). A comparison of thresholds obtained with the two devices has not been reported. In addition, air-conduction thresholds were obtained with DD450 earphones to determine if the reference equivalent threshold sound pressure levels (RETSPLs) for Sennheiser HDA 200 earphones (now out of production) that are in the standards are appropriate for the new Radioear DD450 earphone. Data were collected in compliance with the ISO 389.9-2009 standard which specifies methods for deriving reference equivalent threshold levels. AMTAS, Automated Method for Testing Auditory Sensitivity (Margolis et al., 2010) was used to measure air-conduction and bone-conduction thresholds in the conventional frequency range (250 - 8000 Hz). Air conduction thresholds were measured before testing with each bone vibrator, permitting an analysis of test-retest reliability for thresholds obtained with the new earphone.

Methods

Participants:

- 27 normal-hearing adults (14 male, 13 female)
- Inclusion criteria:
  - Age 18- 25 years inclusive
  - Otoscopic examination within normal limits (no occluding cerumen or other abnormality)
  - No prolonged or frequent exposure to high-level noise
  - No known history of otologic disorders
  - No known family history of genetic hearing disorders
  - Normal results from immittance testing (tympanometric peak pressure > -50 daPa, static admittance > 0.4 mmhos, tympanometric width < 200 daPa)
  - Pure-tone thresholds within normal limits (< 25 dB HL)

DD450

HDA 200

B-81 Bone Vibrator

B-71 Bone Vibrator

Procedures:

Psychoacoustic Determination of RETFLs and RETSPLs:

- GSI AMTAS (Automated Method for Testing Auditory Sensitivity) and a GSI AudioStar audiometer were used to obtain threshold data at octave frequencies from 250 Hz to 8,000Hz.
- Participants were tested once with the B-81 vibrator and once with the B-71 in random order.
- HDA200 data were obtained from a previous study (Smull et al., 2016).
- RETSPLs and RETFLs for the DD450 and B-81 transducers were derived by adding the mean threshold differences between the transducer and the reference transducer (HDA 200 and B-71) to the standard reference levels (ANSI S3.6-2010; ISO 389-8-2004).
- AMTAS procedure:
  - Forehead bone vibrator placement.
  - The DD450 headphone was worn for both trials to measure air-conduction thresholds and to present masking using an adaptive approach to allow for ear-specific bone-conduction thresholds for both the B-81 and B71 bone vibrators.
  - Air-conduction thresholds were obtained for 250 Hz, 500 Hz, 1 kHz, 2 kHz, 3 kHz, 4 kHz, and 8 kHz.
  - Bone-conduction thresholds were obtained for 250 Hz, 500 Hz, 1 kHz, 1.5 kHz, 2 kHz, 3 kHz, and 4 kHz.
  - Bone vibrators were calibrated to standard B-71 RETFLs with a -14.1 dB correction at 4 kHz (see Margolis et al., 2013)

Results

Bone Conduction Thresholds

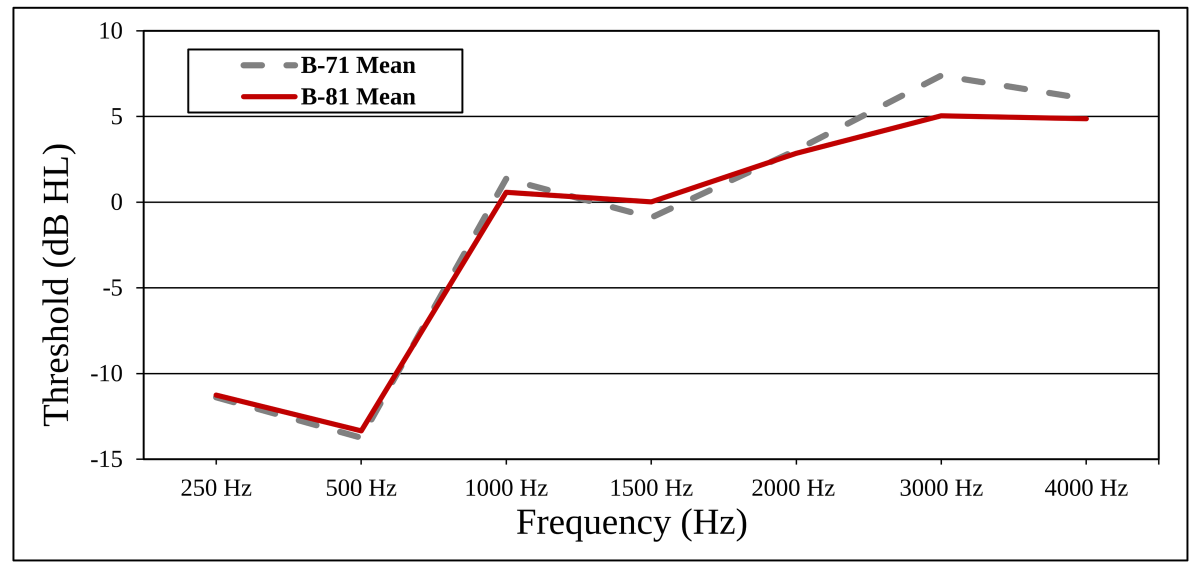

Figure 1. Mean thresholds for the B-81 (red) and B-71 (gray) are within 8 dB of 0 dB HL except at 250 Hz and 500 Hz, due to the occlusion effect at lower frequencies. Thresholds for both transducers closely approximate each other with no significant difference between the two (F(1,26)=.814, p =.375).

Air Conduction Thresholds

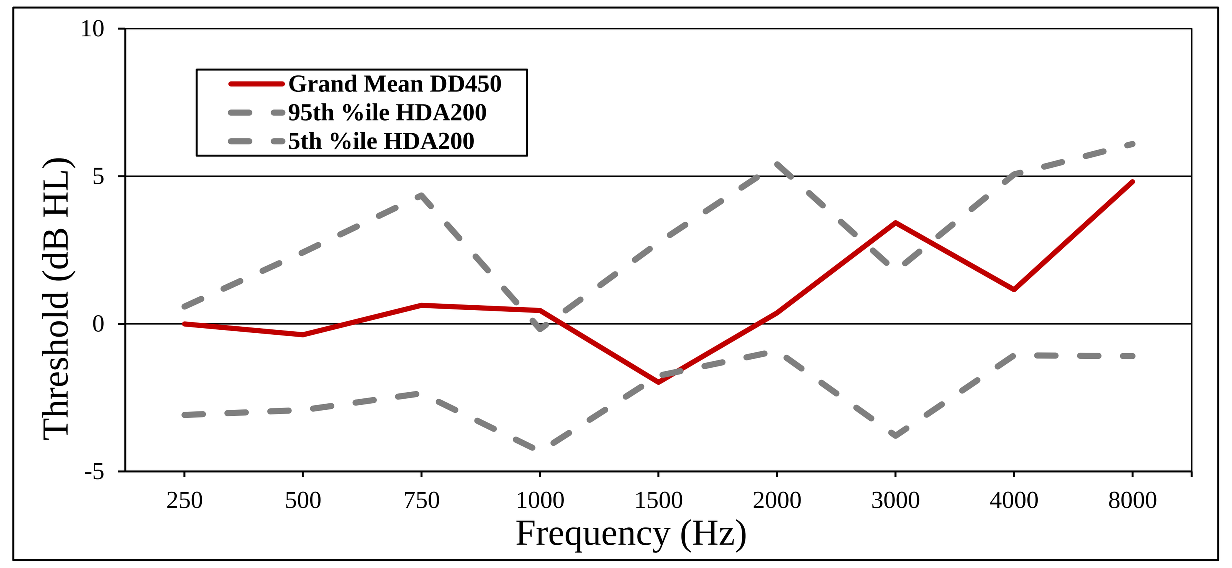

Figure 3. Mean thresholds for the DD450 (solid line) are within 5 dB of 0 dB HL, and fell within the 5th and 95th percentile confidence interval for the HDA200 (dashed gray lines) for all frequencies from 250 Hz to 8000 Hz except at 1000 Hz and 3000 Hz.

Test-Retest Air Conduction Thresholds

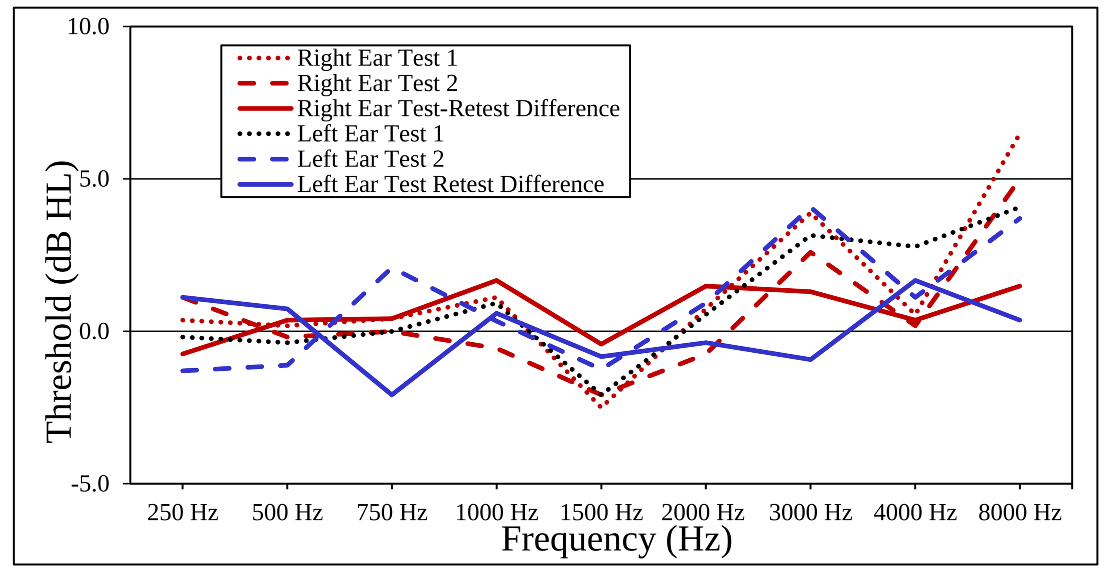

Figure 5. DD450 threshold means are plotted by ear (red for right, blue for left), dotted lines and dashed lines depict means of each test run. The solid lines show the test-retest difference. These differences are within +/- 5 dB HL. There is no significant difference between Test 1 and Test 2 thresholds (F(1,26) = 2.603, p = .119).

RETFLs

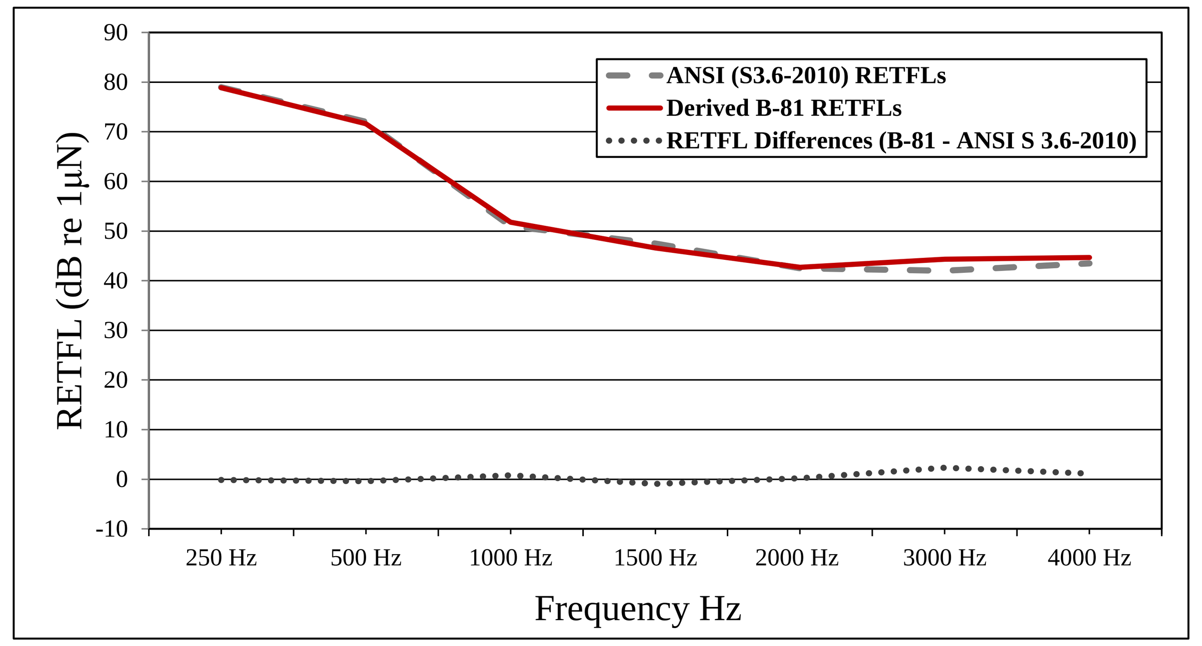

Figure 2. RETFLs derived for the B-81 (red line) were nearly identical to ANSI 2010 standard RETFLs (dashed gray line) with small differences above 2000 Hz.

RETSPLs

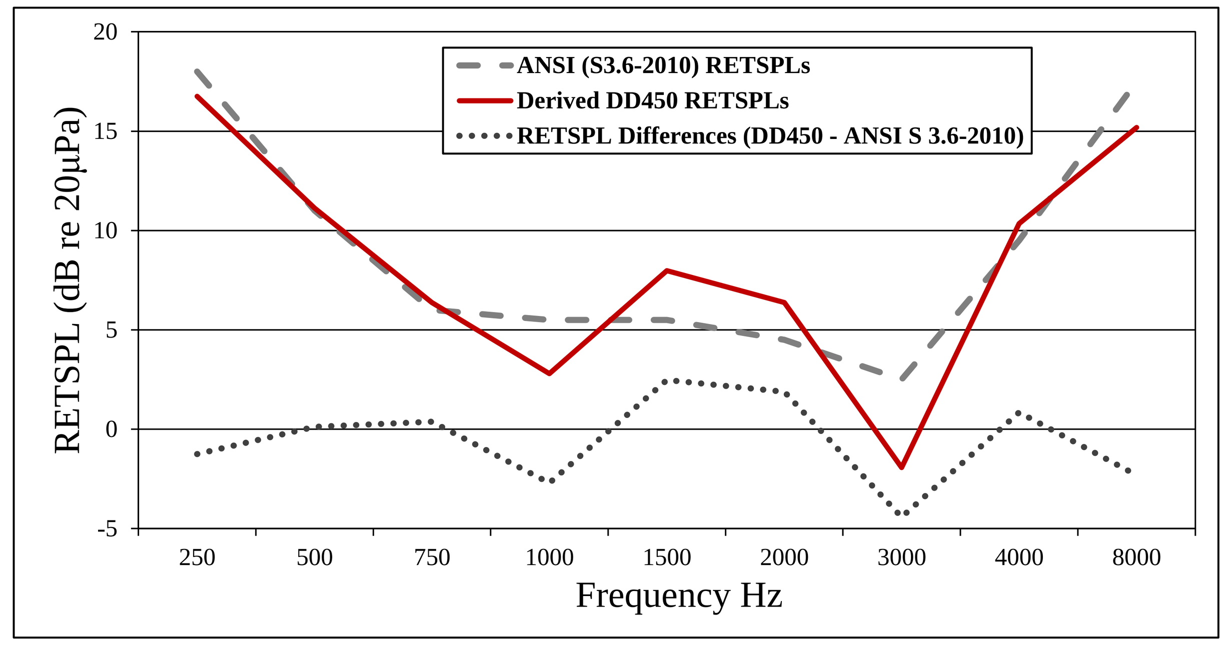

Figure 4. RETSPLs are plotted for the DD450 (red line) and HDA200 (dashed gray line). Differences between RETSPLs for the DD450 and HDA200 (dotted gray line) indicate slight differences between performance of the two earphones, but these differences are small and fall within +/- 5 dB of 0 dB re: 20µPa.

False 4-kHz Air-Bone Gaps

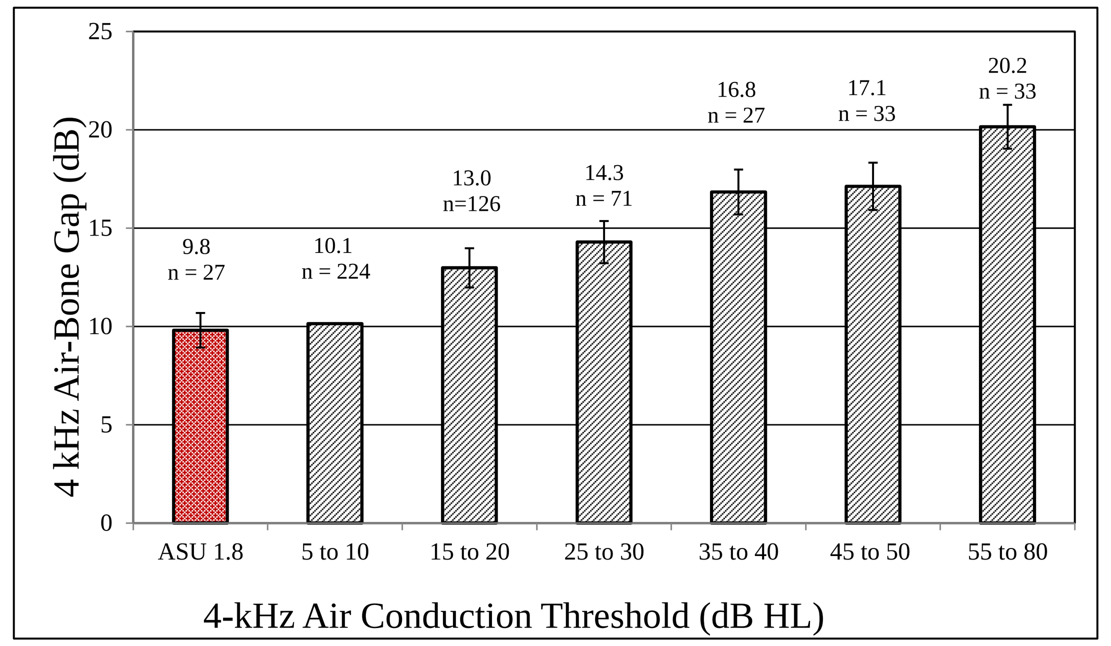

Figure 6. False 4-kHz air-bone gaps resulting from the incorrect RETFL at that frequency. Gray bars are from Margolis et al. (2013). The red bar is from the current study. Average air-bone gaps increase monotonically with the air-conduction threshold, ranging from 10 dB for normal hearing listeners to 20 dB for listeners with severe sensorineural hearing loss.

Discussion and Conclusions

- Bone Conduction Thresholds: There is no significant difference between mean bone conduction thresholds obtained using the B-81 and B-71 bone oscillators for frequencies from 250 Hz through 4000 Hz. Mean thresholds are within 10 dB of 0 dB for all test frequencies except for 250 Hz and 500 Hz. We believe this may be due to the occlusion effect when masking with the circumaural headphones.
- RETFLs: There is no significant difference between RETFLs derived for the B-81 and B-71 bone oscillators. These results suggest equal performance between the two oscillators.
- Air Conduction Thresholds: Mean thresholds for the DD450 are within 5 dB of 0 dB HL, and fell within the 5th and 95th percentile confidence interval for the HDA200 for all frequencies from 250 Hz to 8000 Hz except at 1000 Hz and 3000 Hz. Even though mean thresholds at 1000 Hz for the DD450 fall outside the 5th to 95th percentile confidence intervals for the HDA200, the mean thresholds are actually closer to 0 dB and indicating that the standard RETSPL is appropriate at that frequency.
- RETSPLs: DD450 RETSPLs are very close to HDA200 RETSPLs with slight differences at 1000 Hz, 1500 Hz, 2000 Hz, 3000 Hz, and 8000 Hz. These differences suggest that there are slight differences in performance between the two transducers; however, results suggest that the RETSPLs in the Standard (ANSI S3.6) are still appropriate for the DD450 due to how small these differences are (within +/- 5 dB of 0dB re: 20µPa),
- Test-Retest Air-Conduction Thresholds: Mean test-retest differences for pure-tone thresholds with the DD450 are within +/- 5 dB. This suggests good test-retest reliability with the DD450 and good test-retest validity for AMTAS.
- 4 kHz Air-Bone Gap: The 4-kHz air-bone gap that occurs when bone conduction is calibrated to the standard RETFL for the normal-hearing subjects tested in this study is consistent with previously reported results (Margolis et al., 2013).

References

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Acknowledgment

This project was supported by **DGS Diagnostics A/S**

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