Electroacoustic Evaluation of Pediatric-Focused Hearing Assistive Devices/Systems in Different Digital Signal Transmission Arrangements

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INTRODUCTION

- Hearing assistive devices/systems (HADS) are intended to facilitate hearing by providing amplification of an acoustic signal and/or improving signal-to-noise ratio (SNR).
- Digital modulated (DM) signal transmission systems operate on a 2.4 GHz bandwidth and transmit signals directly from a transmitter or remote microphone (RM) on the talker to a receiver worn by the listener.
- ANSI S3.47-2014 provides recommended measurements for performance verification.
- American Academy of Audiology Clinical Practice Guidelines (AAA-2011 Guidelines) state electroacoustic transparency occurs when equal inputs to the HADS and hearing aid (HA) microphone produce equal outputs from the HA.

PURPOSE

- Part 1 :
  The primary goal of this study was to compare and verify the electroacoustic analysis (EAA) of HADS in different DM transmission arrangements per ANSI S3.47-2014 standard.
- Part 2 :
  The secondary goal was to evaluate the transparency of HADS based on AAA-2011 Guidelines.

METHOD

HAs with undamped ear hooks

- Oticon Opn Play 2 BTE PP
- Oticon Opn 3 BTE PP

HA programming

- Part 1 (EAA measurement):
  Flat 100 dBHL sensorineural hearing loss (SNHL) with maximum power output
- Part 2 (Transparency measurement):
  Flat 50dBHL & 100dBHL SNHL
- Desired Sensation Level (DSL v5.0) fitting formula with junior fitting mode and average real-ear-to-coupler difference values (Seewald et al. 2005) for a 10-year-old listener
- Adaptive features such as noise reduction and directionality disabled

Electroacoustic analysis procedure

- HA attached to a 2cc coupler and output measured in a calibrated Fonix 8000 hearing aid test system-Frye Electronics, Inc.
- All measurement values were obtained with five measurements when variables were held constant.

METHOD

Transmission arrangement	Transmitter unit	Hearing aids	Receiver unit
Direct audio input	Phonak Roger Touchscreen set to verification mode	Oticon Opn Play 2 BTE PP & Oticon Opn 3 BTE PP	Phonak Roger X receiver* (Easy gain=0) with FM 10 audio shoe
Induction loop			Phonak Roger MyLink (Volume=midway) with HA set at telecoil program
Direct digital streaming	Oticon ConnectClip set to remote microphone mode & default volume		HA paired with ConnectClip (HA/RM ratio=0 dB)

Table 1. Equipment and test setups of three transmission arrangements. Note: BTE=behind-the-ear; PP=plus power; HA=hearing aid; RM=remote microphone.
** A second Roger X receiver was required because measurements obtained with the first one showed inconsistent transparency.*

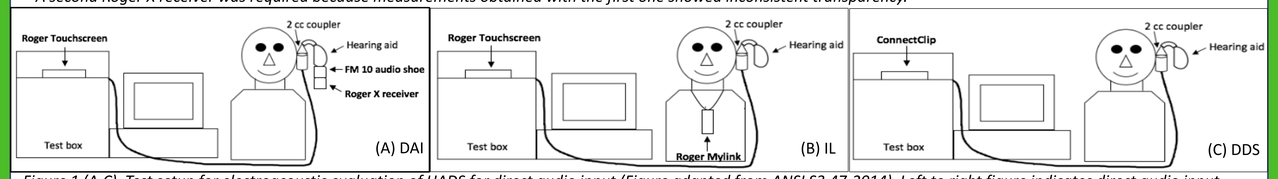

Figure 1 (A-C). Test setup for electroacoustic evaluation of HADS for direct audio input (Figure adapted from ANSI S3.47-2014). Left to right figure indicates direct audio input (DAI), induction loop (IL), direct digital streaming (DDS) transmission arrangements.

Part 1: EAA measurement	Description	HA volume control
HFA OSPL 90	HFA outputs with a 90-dB SPL input	Full-on
HFA FOG 50	HFA outputs with a 50-dB SPL input	
HFA OSPL 60	HFA outputs with a 60-dB SPL input	Reference test gain
Noise level with no input	OSPL in the coupler with no input	
EIN	Equivalent input noise	

Table 2. EAA measurements described in the ANSI S3.47-2014. Note: OSPL=output sound pressure level; FOG= full on gain; HFA=high frequency (1,1.6, 2.5kHz) average.

Part 2: Transparency measurement	Inside test box	Outside test box	Signal level (dB SPL)
EHA 65	HA	Touchscreen off or ConnectClip off	65
EHA/DM 65	HA + DM receiver	Touchscreen off	65
EDM/HA 65	Touchscreen on	HA + DM receiver	65
ERM/HA 65	ConnectClip on	HA	65

Table 3. Measurements to determine transparency (Difference between three-frequency (.75, 1, 2kHz) average outputs of the HA and HADS with 65 dB SPL inputs should be within 2 dB based on AAA-2011 Guidelines). Note: E=electroacoustic; HA=hearing aid, DM=digital modulated; RM=remote microphone.

RESULTS

Part 1: EAA measurements across HA models and transmission arrangements according to ANSI S3.47-2014.

- Clinically-significant differences were not observed for HFA OSPL 90 (<2dB).
- Clinically-significant differences were observed for HFA FOG 50, HFA OSPL 60, noise level with no input and EIN (>2dB).

Mean (SD)	OSPL90		HFA FOG 50		HFA OSPL 60		Noise level with no input		EIN	
	Oticon Opn Play 2 BTE PP	Oticon Opn 3 BTE PP	Oticon Opn Play 2 BTE PP	Oticon Opn 3 BTE PP	Oticon Opn Play 2 BTE PP	Oticon Opn 3 BTE PP	Oticon Opn Play 2 BTE PP	Oticon Opn 3 BTE PP	Oticon Opn Play 2 BTE PP	Oticon Opn 3 BTE PP
DAI	**123.4** (0.22)	**123.38** (0.11)	**61.88** (1.33)	**61.76** (0.13)	**47.18** (0.39)	**47.00** (0.07)	**71.60** (2.06)	**72.98** (1.64)	**26.24** (1.59)	**27.26** (0.50)
IL	**123.88** (0.11)	**123.86** (0.05)	**66.28** (0.36)	**69.24** (0.72)	**49.03** (1.22)	**51.02** (0.53)	**71.72** (5.08)	**72.58** (1.56)	**22.00** (0.28)	**20.60** (0.53)
DDS	**123.84** (0.11)	**123.94** (0.05)	**65.32** (0.28)	**65.96** (0.11)	**46.90** (0.36)	**47.26** (0.05)	**69.88** (3.72)	**67.62** (1.56)	**22.96** (0.23)	**20.58** (0.39)

Table 4. Electroacoustic measurement values in the two hearing aid models coupled with three DM transmission arrangements. Note: See text for abbreviations.

Part 2: Transparency measurements across HA models and transmission arrangements according to AAA-2011 Guidelines.

Transparency values			Flat 50 dBHL SNHL		Flat 100 dBHL SNHL	
			Mean (SD)	Transparency	Mean (SD)	Transparency
Opn Play 2 BTE PP	DAI	EHA/DM65 - EDM/HA65	-1.28(0.59)	✓	1.48(0.37)	✓
	IL	EHA65 - EDM/HA65	-1.78(1.00)	✓	-1.17(0.46)	✓
	DDS	EHA65 – ERM/HA65	-0.88(0.49)	✓	-0.18(1.79)	✓
Opn 3 BTE PP	DAI	EHA/DM65 - EDM/HA65	-0.87(1.09)	✓	0.48(0.25)	✓
	IL	EHA65 - EDM/HA65	-0.10(1.20)	✓	-0.02(0.52)	✓
	DDS	EHA65 – ERM/HA65	-1.35(0.84)	✓	-0.80(0.20)	✓

Table 5. Electroacoustic transparency measurement values for each hearing aid coupled with three digital transmission arrangements. Note: BTE=behind-the-ear; SNHL=sensorineural hearing loss; DAI=direct audio input; IL=induction loop; DDS= direct digital streaming.

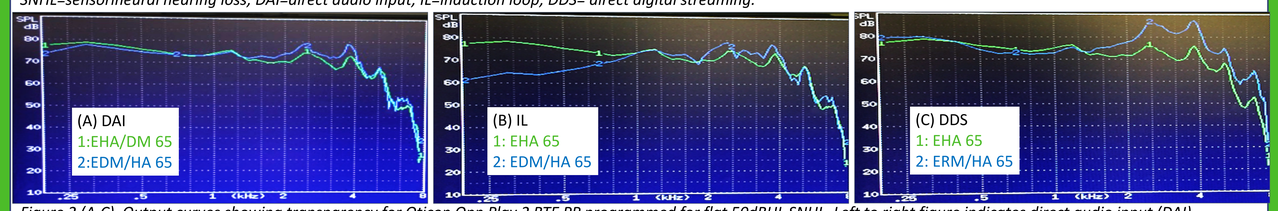

Figure 2 (A-C). Output curves showing transparency for Oticon Opn Play 2 BTE PP programmed for flat 50dBHL SNHL. Left to right figure indicates direct audio input (DAI), induction loop (IL), direct digital streaming (DDS) transmission arrangements.

SUMMARY

Part 1 (EAA measurement):

- EAA across HADS in three digital transmission arrangements when the HAs were programmed to 100 dB HL SNHL revealed variable results in
  - HFA FOG 50 (range 62-69 dB SPL)
  - HFA OSPL 60 (47-51 dB SPL)
  - Noise level with no input (68-73 dB SPL)
  - EIN (21-27 dB)
- However, HFA OSPL90 was similar across the three arrangements (range 123-124 dB SPL).

Part 2 (Transparency measurement):

- Transparency was met when the difference between three-frequency (.75, 1, 2kHz) average outputs of the HA and HADS with 65 dB SPL inputs was within 2 dB.
- All three transmission arrangements revealed desired transparency in both hearing aids for both degrees of hearing loss without any adjustments required.
  - Direct audio input: Output for HA and HADS matched within 2-3 dB across the frequency spectrum (Figure 2A).
  - Induction loop: Reduced outputs were noted below 1kHz. Transparency was still achieved based on the three-frequency average (Figure 2B).
  - Direct digital streaming: Increased outputs were noted above 2kHz. Transparency was still achieved based on the three-frequency average (Figure 2C).

IMPLICATIONS

- EAA findings suggest the need for specification sheets for HADS across manufacturers to determine if the devices are meeting specifications.
- Evaluation across HADS in different digital transmission arrangements revealed desirable transparency per AAA-2011 Guidelines.
- Frequency output curves may not be closely matched even when transparency was achieved. This supports the critical need of electroacoustic evaluation for HADS.

ACKNOWLEDGEMENTS

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