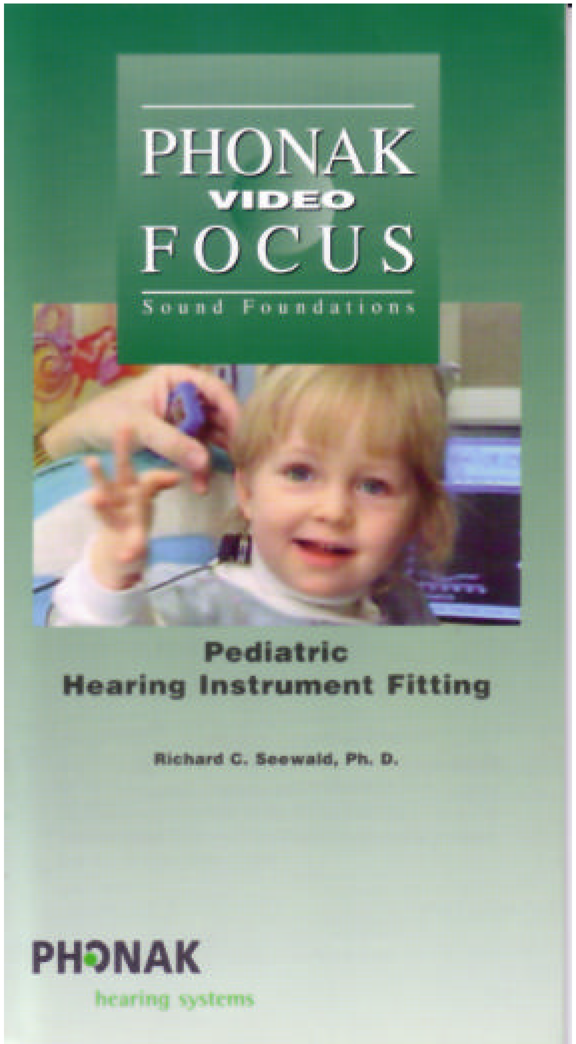


PHONAK VIDEO FOCUS
Sound Foundations

Pediatric Hearing Instrument Fitting

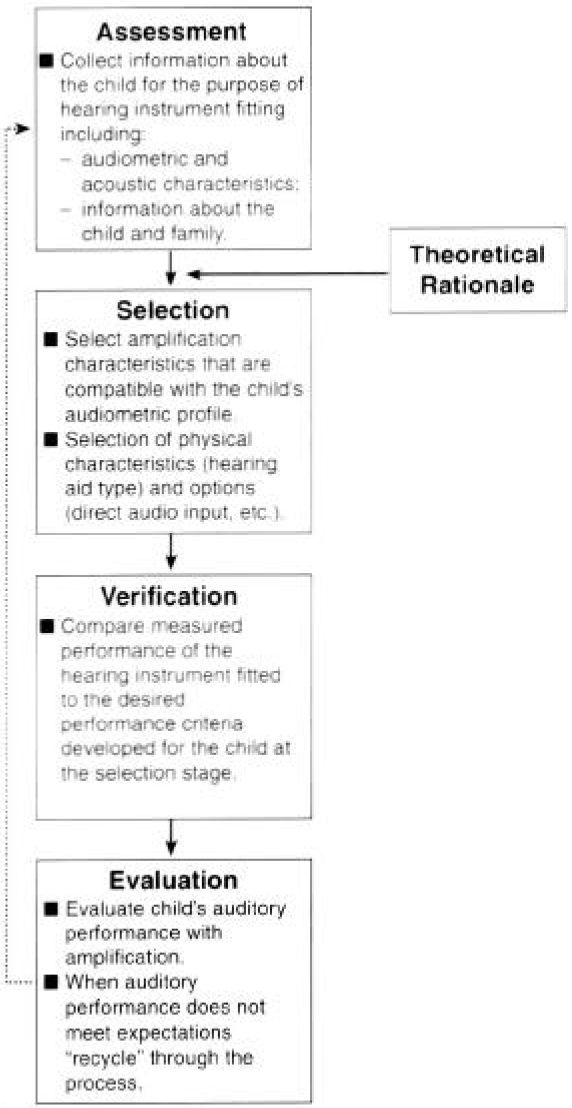
This booklet is designed to supplement the Phonak Video Focus "Pediatric Hearing Instrument Fitting". The figures and references contained were selected to further clarify the pediatric hearing instrument fitting procedures presented in the videotape, and to direct interested readers to pertinent literature.

This booklet has been organized according to three sections:

1. assessment for hearing instrument fitting;
2. hearing instrument selection and fitting, and
3. electroacoustic verification procedures.

As the videotape illustrates, the process of hearing instrument fitting with young children is conceptualized as a sequential series of well-integrated stages. This conceptualization of the fitting process is shown in Figure 1 and described in detail in Seewald, Moodie, Sinclair & Cornelisse (1996).

Figure 1: Conceptualization of the hearing instrument fitting process used in the DSL method.



Assessment for hearing instrument fitting

There are two important components to the assessment process for hearing instrument fitting: measurement of individual acoustic characteristics, and measurement of auditory characteristics.

Measurement of individual acoustic characteristics: Real-Ear to Coupler Difference (RECD)

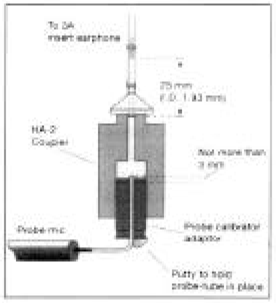
The Real-Ear to Coupler Difference (RECD) measurement procedure is an integral part of the fitting method presented in this videotape. It allows the clinician to precisely define the correction from 2cc coupler to real-ear for the individual child using his/her own custom earmold. Clinical implementation of the RECD measurement procedure offers several advantages including:

- a more precise definition of hearing levels;
- the ability to measure the unique acoustic properties of the child's ear and earmold coupling, eliminating the need to rely on average adult values;
- the capability to perform all hearing instrument response shaping in the controlled conditions of the hearing aid test box: and
- a substantial reduction in the amount of time and degree of cooperation required of the child in the fitting process.

Most real-ear measurement systems can be configured to conduct the RECD measurement procedure. The system must allow use of an insert earphone (as opposed to the loudspeaker) and deactivation of the reference microphone for measurement of the RECD.

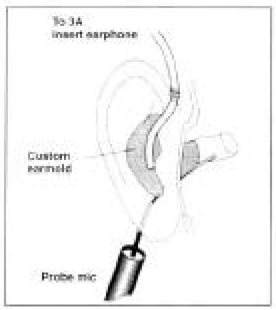
The RECD measurement procedure is demonstrated in schematic version below. Specific measurement instructions are provided in Moodie, Seewald & Sinclair (1994), and Seewald (1995).

Figure 2: Real-Ear to Coupler Difference (RECD) measurement procedure.



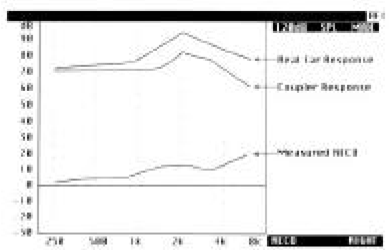
Coupler Measurement

- A probe-tube is inserted into a calibrator adapter and placed into a BTE 2cc coupler.
- A signal is delivered via the insert earphone into the coupler, and the coupler output is measured and stored.



Real-Ear Measurement

- The probe-tube is placed 15–20 mm from the entrance to the ear canal, depending on age and the clinician's judgment of ear canal size.
- The insert earphone is coupled to the ear canal via the child's custom earmold.
- A signal is delivered via the insert earphone into the ear, and the real-ear output is measured and stored.



Calculation of individual RECD values

- The measured RECD is computed by subtracting the coupler response from the real-ear response on a frequency-by-frequency basis.

Measurement of auditory characteristics

The collection of accurate audiometric data is an integral part of the hearing instrument fitting process. The accuracy of the fitting will depend, in part, on the validity of the audiometric data that are applied in selecting amplification characteristics. One issue related to the validity of the audiometric data collected for the purposes of hearing instrument fitting is that audiometers are calibrated referenced to **normalized adult-based criteria**. That is, the traditional decibels hearing level (dB HL) audiogram approach has inherent errors when used for the purposes of defining hearing loss in infants and young children. The hearing instrument fitting approach outlined in this videotape attempts to reduce/eliminate these errors by specifying audiometric data in terms of the sound pressure level (SPL) measured near the child's eardrum. Specifying audiometric data in this manner has two advantages: (1) a more accurate measurement of the child's hearing loss is obtained, (2) the metric is the same as that used to characterize the electroacoustic performance of hearing aids. In this way the important interrelationships between hearing instrument performance and the relevant auditory characteristics of the child can be easily made.

Audiometric assessment with insert earphones and custom earmolds

The use of insert earphones coupled to the child's custom earmolds at the assessment stage is desirable because: (1) insert earphones provide the clinician with individual ear information; (2) the earmold usually provides a better acoustic seal compared to the standard foam eartips; (3) the child will be familiar with the earmold, whereas, they may not be familiar with the standard foam eartip and thus may not allow the clinician to insert the foam eartip.

Measurement of auditory characteristics should always be conducted employing audiometric procedures that are compatible with the developmental age of the child.

Audiometric screening and assessment procedures for infants and young children are addressed in the companion videotape "Pediatric Hearing Assessment" in this Phonak Video Focus series.

The following steps outline a recommended procedure for utilizing the custom earmold in the assessment process.

(1) The tubing on the custom earmold is cut to the length that is necessary for the comfortable fit of the hearing instrument.

(2) The insert earphone is clipped to the back of the child's clothing at the base of the neck.

(3) The custom earmold is inserted into the child's ear, and the nipple of the insert earphone is attached to the earmold (Fig. 3).

(4) In the case of older earmolds, where the tubing has been stretched at the point of the hearing aid earhook, it may be necessary to employ a small piece (7–8 mm) of #16-earmold tubing attached to the insert earphone nipple to ensure a tight fit between the earmold tubing and the insert earphone (Fig. 4).

Figure 3

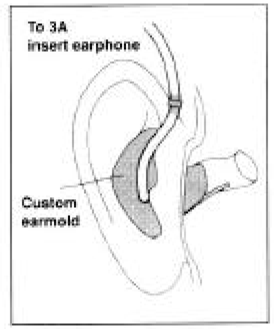
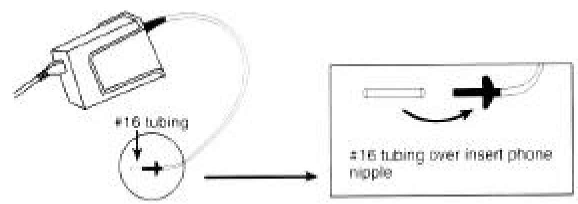


Figure 4



Calculating predicted thresholds (dB SPL) from dB HL threshold data

Insert earphones are calibrated in a 2cc coupler. Consequently, when audiometric assessment is conducted with insert earphones, the child's hearing levels are defined relative to 2cc coupler SPL values. When the difference between a signal delivered into the child's ear and the 2cc coupler (the RECD) is defined, the child's eardrum SPL threshold values can be predicted.

Threshold in dB HL with insert earphones	+	HL/2cc SPL correction	+	Measured RECD values	=	Predicted threshold in dB SPL at child's eardrum

Table 1: Example of a calculation of threshold in dB SPL (eardrum level) from dB HL data.

	FREQUENCY (Hz)			
	500	1000	2000	4000
threshold dB HL	85	95	90	90
(+) HL / 2cc coupler SPL correction	9	4	7	2
(+) measured RECD	6	10	12	7
(=) threshold dB SPL	100	109	109	99

Relevant references

Feigin, J.A., Kopun, J.G., Stelmachowicz, P.G. (1989). Probe-tube microphone measures of ear-canal sound pressure levels in infants and children. *Ear and Hearing*, 10, 254–258.

Moodie, K.S., Seewald, R.C. & Sinclair, S.T (1994). Procedure for predicting real-ear hearing aid performance in young children. *American Journal of Audiology*, 3, 23–31.

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Hearing instrument selection and fitting

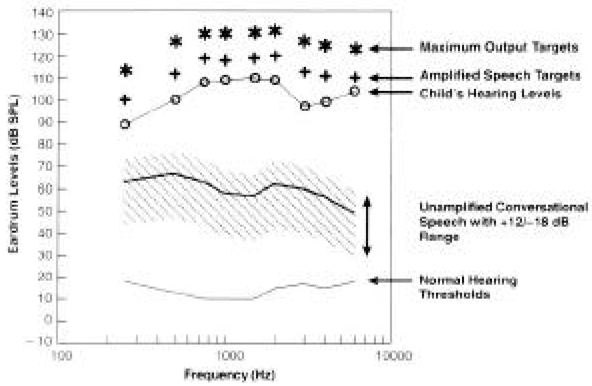
Deriving eardrum SPL hearing instrument performance criteria

The hearing instrument selection, fitting and verification strategies demonstrated in this videotape are based on the Desired Sensation Level (DSL®) Method. Measured audiometric data and real-ear to coupler difference values collected at the assessment stage are entered into the DSL computer program or directly into a real-ear measurement system which incorporates the DSL method. The entered information is used to define the child's predicted auditory area in terms of dB SPL near the eardrum as a function of frequency. The DSL method calculates desired eardrum SPL target levels for amplified speech and maximum output as a function of frequency. All of this information is presented in a visual display called an SPLogram.

Understanding an unaided SPLogram

Figure 4 illustrates an unaided SPLogram used in the DSL method (version 4.1). As shown, the audiometric test results and desired hearing aid performance are referenced to dB SPL near the eardrum as a function of frequency.

Figure 5: Unaided SPLogram.



Deriving 2cc coupler performance criteria

Once eardrum SPL performance criteria for the hearing instrument have been developed, the DSL method applies appropriate transfer functions and correction factors to derive a corresponding set of 2cc coupler-based values. The calculation of 2cc coupler target values should utilize the child's measured RECD values whenever possible. If an RECD measurement cannot be obtained for a child, then age-appropriate average RECD values should be used (rather than adult-based average values). The following schematic illustrates how the eardrum SPL performance criteria for amplified speech and maximum output are converted to 2cc coupler-based target values (gain and Output Sound Pressure Level [OSPL]).

Gain

Real-ear amplified speech target – Speech input level (dB SPL) – RECD – Microphone location effects = 2cc coupler user gain target

Table 2: Example of a calculation of 2cc coupler-based target values of user gain.

	FREQUENCY (Hz)			
	500	**1000**	**2000**	**4000**
Real-ear amplified speech target (dB SPL)	112	118	120	111
(–) speech input levels (dB SPL)	64	55	50	42
(–) measured RECD	6	10	12	7
(–) micro-phone location effects	1	1	4	4
(=) 2cc coupler user target	41	52	54	58

OSPL

Real-ear max. output target – RECD = 2cc coupler OSPL target

Table 3: Example of a calculation of 2cc coupler-based target values of OSPL.

	FREQUENCY (Hz)			
	500	1000	2000	4000
Real-ear max. output target (dB SPL)	126	130	131	125
(–) measured RECD	6	10	12	7
(=) 2cc coupler OSPL target	120	120	119	118

The target 2cc coupler gain and OSPL values can now be used for the purposes of selecting an appropriate hearing instrument for the child to be fitted.

Relevant references

Cornelisse, L.E., Seewald, R.C. & Jamieson, D.G. (1994). Wide-dynamic range compression hearing aids: The DSL® [i/o] approach. *Hearing Journal*, 47, 23–26.

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Electroacoustic Verification Procedures

Once a hearing aid with appropriate earmold coupling has been chosen, based on the desired 2cc coupler performance criteria, the process continues to the verification stage. At this stage measured performance of a specific hearing instrument is compared to the desired performance criteria developed for the child.

Real-ear verification measures of hearing aid performance are not always possible with young children. Consequently, the DSL method enables verification of hearing instrument performance using the controlled measurement conditions of the 2cc coupler. Because the child's RECD has been measured, the real-ear hearing instrument performance can be accurately predicted on the basis of the 2cc coupler-based measures. The following equations illustrate how this is achieved.

Measured 2cc coupler user gain + RECD + Microphone location effects + Speech input levels (dB SPL) = Predicted amplified speech (dB SPL)

Measured 2cc coupler OSPL + RECD = Predicted max. output (dB SPL)

The appropriate 2cc coupler-based verification targets for the child shown in the unaided SPLogram are provided in Table 4.

Table 4: Example of a 2cc coupler-based verification target.

	FREQUENCY (Hz)			
	500	1000	2000	4000
2cc coupler user gain target values	41	52	54	58
2cc coupler OSPL target values	120	120	119	118

The DSL 2cc coupler-based verification procedure outlined below is described in specific detail in Moodie (1996), and Seewald (1995).

The process of electroacoustic fitting and verification involves two basic steps: (1) setting output limiting characteristics at 90 dB SPL and (2) setting gain characteristics at appropriate speech-weighted input levels.

Setting the maximum power output of the hearing instrument

Setting the MPO in ear level hearing instruments is dictated by two peaks in the hearing instrument response. Typically one peak occurs at approximately 1000 Hz, due to the earhook resonance, with the second peak occurring at approximately 2500 Hz, due to receiver resonance. It is necessary to ensure that these peaks do not exceed the target values for maximum output. Acoustic filters can be used to dampen the 1000 Hz peak, and thus reduces the amount by which the hearing instrument output must be adjusted. This can assist in maintaining high-frequency output. The test signal used to verify the MPO setting of the hearing instrument is a 90 dB SPL pure-tone.

Setting the volume control wheel, tone controls and other hearing instrument parameters

The speech-weighted input levels used by the DSL method to determine hearing instrument gain characteristics are indicated in Table 5.

Table 5: Speech-weighted input levels used in the DSL method.

	FREQUENCY (Hz)								
	250	500	750	1000	1500	2000	3000	4000	6000
assumed speech input levels	63	**64**	60	55	51	**50**	46	42	42

(Most 2cc coupler test box systems will require the clinician to "round-up" these input levels, as they will only increase or decrease the signal input level in 5 dB steps. For example, gain would be set at 500 Hz using a 65 dB input signal.)

Gain is initially set at 2000 Hz by adjusting the volume control to match the 2cc coupler target using a 50 dB SPL pure-tone input signal. This will optimize the high-frequency response. A higher frequency may be chosen depending on the child's audiometric configuration.

Next, gain is set at 500 Hz using a 65 dB SPL pure-tone input signal by adjusting available hearing instrument controls (tone, low-cut etc). The purpose here is to compensate for both the slope of the audiogram and difference in speech input levels between the low- and high-frequency area. Another frequency (e.g. 1000 Hz) could be used, depending on the steepness of the audiometric slope and kneepoint of the hearing instrument.

Once these initial adjustments have been accomplished, output and gain are evaluated at all other frequencies in order to determine how well the hearing instrument meets the desired performance criteria (tables 6 and 7).

Table 6: Calculation of difference between measured 2cc coupler user gain and 2cc coupler-based user gain target values.

	FREQUENCY (Hz)			
	500	1000	2000	4000
measured 2cc coupler gain	40	54	52	48
(–) 2cc coupler gain target values	41	52	54	58
(=) difference	– 1	2	– 2	– 10

Table 7: Calculation of difference between measured 2cc coupler OSPL and 2cc coupler-based OSPL target values.

	FREQUENCY (Hz)			
	500	1000	2000	4000
measured 2cc coupler OSPL	116	120	116	111
(–) 2cc coupler OSPL target values	120	120	119	118
(=) difference	– 4	0	– 3	– 7

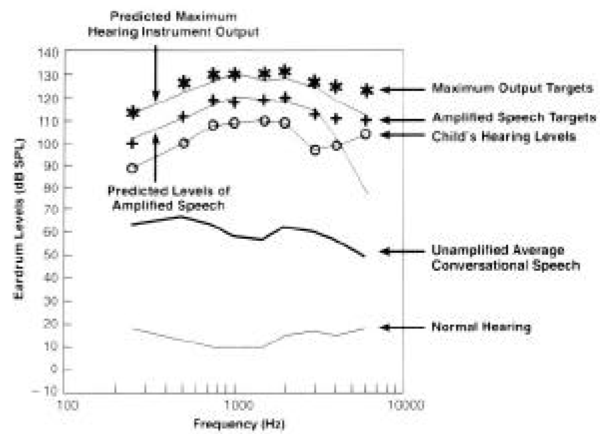
It should be noted that this process would represent hearing aid performance under static input conditions. It may not necessarily represent the performance of the aid under dynamic speech-like conditions and does not initially

consider effects of distortion and/or compression on speech audibility or perception. Therefore, the clinician is encouraged to apply additional electroacoustic measures whenever possible.

Understanding an aided SPLogram

For verification purposes, the measured 2cc coupler hearing instrument performance is transformed by the DSL software system to predicted eardrum SPL levels as a function of frequency. These predicted eardrum SPL values for amplified speech and maximum output are then displayed on an aided SPLogram and can be evaluated relative to the desired performance criteria. The aided SPLogram in Figure 5 represents the results of the verification procedure outlined above which have been transformed to SPL values by the DSL method.

Figure 6: Aided SPLogram.



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Materials and instrumentation systems shown in videotape

Computer-Assisted Implementation of The DSL Method: Version 4.1
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E-mail: DSL@audio.hhcru.uwo.ca
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Long Island City, NY 11106-4416
U.S.A.
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