AMPLIFICATION PROTOCOLS FOR INFANTS AND CHILDREN

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The EAR Foundation of AZ 4th Annual Audiology Seminar
Friday September 11, 2009

FYI

- Implementation of Universal Newborn Hearing Screening (UNHS) programs in the United States has significantly reduced the average age of identification from 30 months of age to under 6 months
- Without appropriate opportunity to learn language, children who are hard of hearing or deaf will fall behind their hearing peers in language, cognition, and social-emotional development

FYI

- Infants who are hard of hearing or deaf who receive intervention before 6 months of age maintain language development commensurate with their cognitive abilities through the age of 5 years

Amplification for Children

- When fitted appropriately, hearing aids/FM technology will in most instances enable the child to use residual hearing so that speech and language can develop on or near an age-appropriate pace (with appropriate intervention for aural re/habilitation).

Amplification for Children

- Realistic understanding
  - Will NOT enable a HI child to perform normally in all situations
  - Goal is to make speech audible at safe and comfortable listening levels at a sensation level that provides as many acoustic speech cues as possible
  - Make soft speech audible, speech and environmental sounds comfortable, and loud sounds not uncomfortable

Amplification for Children

- Reception of soft speech is particularly important for incidental language learning (which accounts for a very large portion of language learning), self-monitoring of speech, and ease of communication in various real-world listening environments

Amplification for Children

- There is a need to base clinical decisions on research, but the pace of technological innovation in hearing aids exceeds that of supporting research
- Today's advanced features and styles of hearing aids (noise reduction, directional microphones, receiver-in-the-ear (RITE), and open-canal) are being fitted on children.

Amplification for Children

- Every audiologist who fits advanced devices (or "traditional") on children and infants has the responsibility to verify those fittings

Amplification for Children

- The manufacturer's "first fit" default setting should not be used in an initial fit of new amplification on infants and young children
- Fitting a hearing aid without independent verification is inappropriate, and research indicates that for "average" speech input, the difference in gain can be up to 21 dB between hearing aid brands (for the same audiogram and an "average" RECD for a 6-month-old), most notably in the higher frequencies

Amplification for Children

- The discrepancies between hearing aids from different manufacturers are even greater when the input is loud speech
- Generally speaking, the first fits of some manufacturers provide too much amplification, though some provide too little.
- Neither scenario is appropriate for a patient attempting to learn speech and language

Outline: The Fitting Process

ASSESSMENT

SELECTION

VERIFICATION

VALIDATION

The Fitting Process

- This is a good way to organize the amplification process for infants and young children
- If you don't see what you want in the final stage (Validation), you can systematically go back through each stage to find the error

American Academy of Audiology - Pediatric Amplification Protocol October 2003

- Document created to address the significant need for guidance in this area of Audiology
- Consisted of the following areas
  - Personnel Qualifications
  - Candidacy
  - Pre-selection Issues and Procedures
  - Circuitry- Signal Processing
  - Hearing Instrument Selection/Fitting Considerations
  - Verification
  - Hearing Instrument Orientation and Training
  - Validation
  - Follow-up and Referral

American Academy of Audiology - Pediatric Amplification Protocol October 2003

- "Audiologists working with young children should have experience with amplification and management of infants and children with hearing loss and have the test equipment necessary to complete all tests for hearing aid selection, evaluation, and verification procedures described herein."

American Academy of Audiology - Pediatric Amplification Protocol October 2003

- "Facilities that lack the expertise or equipment should establish consortial arrangements with those who do"

Identification

- Otoacoustic Emissions
- Rarefaction and condensation clicks, frequency-specific tone bursts (500-4000 Hz), and bone-conduction testing
- Behavioral Audiometry

  -VRA or CPA (depending upon developmental age)
- Speech Detection and Recognition measures when appropriate

Threshold Data

- It is critical to note that click threshold data from ABR are *not* sufficient for fitting amplification

Identification

- Child and family history
- Otoscopic inspection
- Parental report of any auditory behaviors
- Observation of the child's behavioral responses to sound
- Middle Ear testing
  - acoustic immittance, bone conduction ABR, and acoustic reflexes

Identification

- At the conclusion of the evaluation the audiologist should:
  - Describe to the family the child's hearing abilities
  - Recommend additional assessments by other professionals as needed
  - Refer the infant and family to appropriate resources
  - Explain the implications of hearing loss to the caregivers
  - Send a report detailing the child's hearing loss to all involved parties

Initiation of Amplification

- Ear Molds
  - No child is too young for earmold impressions
  - Earmolds should be made of a soft material (vinyl is preferable) for safety and comfort, and need to be replaced three or four times a year (or whenever feedback occurs at optimal settings, fit becomes loose, or comfort issues arise)

Initiation of Amplification

- Retention devices and options include Huggies™, toupee tape, retention cords (Critter Clips™), and headbands.
- The fitting process involves counseling the parents on care and maintenance of the hearing instruments

Selection/Verification

- Pre-Measurement Issues
  - Probe tube calibration
  - Hearing Aid Test box calibration
  - Otoscopic examination
  - Loudspeaker location
  - Probe tube placement

Selection/Verification

- Selection of a hearing instrument can occur either before or after measurement of the real-ear-to-coupler difference (RECD)
- Verification of a hearing instrument and its gain characteristics is best achieved with probe-microphone and RECD measures using speech signals presented at multiple input levels
- This allows the audiologist to evaluate the hearing aid and its performance across a range of listening levels

Real Ear to Coupler Difference (RECD) Generalities

- Real-ear-coupler-differences are used to individualize the HL to SPL transform (takes the HL data from a behavioral evaluation and converts it to SPL at the child's TM)
- This is important in a population whose ear canals and eardrum impedance generally are different from the adult averages (insert earphones, SF, and headphones are typically calibrated to the "average adult" ear canal

RECD Generalities

- In addition, the RECD is used to adjust the electroacoustic fitting so the final output in the real-ear will be correct for an individual child

RECD

- What is it?
  - "Difference in decibels, as a function of frequency, between the SPL at a specified measurement point in the ear canal and the SPL in a 2cc coupler for a specified input signal."

RECD

- What is it?
  - "Difference in dB across frequencies between the SPL measured in the real ear and in a 2cc coupler, produced by a transducer generating the same input signal."

RECD

- Why should I do it?
  - Most useful application: Prediction of real-ear output when measuring HA in 2cc coupler
  - The RECD is used to convert HA performance measured in a 2 cc coupler into REAL EAR HA performance
  - This measurement is especially important when real-ear aided response (REAR) cannot be measured (for example, with a very young, wiggly or noisy child)

RECD

- Target values for gain and output are determined through the use of a prescriptive formula (such as DSL v.5 or NAL-NL1 or NAL-NL2, which uses the hearing sensitivity data (obtained via behavioral techniques or ABR) and the RECD

RECD

- If you know the acoustic difference between a 2 cc coupler and a child's occluded ear canal then you can add this difference to the HA coupler response to predict what is happening in the child's real ear
- REAR can be predicted to within approximately 2 dB

Predicting HA Output

- Why do we want to predict HA output?
  - We will know the levels of amplified sound delivered into the patient's ear canal
  - Unique acoustic properties of the ear and earmold coupling (if RECD is conducted with EM) will be accounted for. Avoids errors that occur when using "average" values

Predicting HA Output

- Why do we want to predict HA output?
  - All HA response shaping can be performed in the HA test chamber under highly controlled acoustic conditions
  - Degree of cooperation and amount of time required from the patient in the fitting process is greatly reduced

Steps needed to collect real ear data in infants:

- The procedure can be completed in both ears in less than 10 minutes
- All subsequent measures can be made in the test box

Steps needed to collect real ear data in infants:

- Present stimulus into a standard 2-cc coupler via an insert earphone (of course you've calibrated your system)
- Enter the audiogram (dB HL or ABR thresholds)
- Present the chosen stimulus in a standard 2-cc coupler via an insert earphone. An SPL is measured, which is the coupler response

Steps needed to collect real ear data in infants:

- A Probe Microphone is placed into the child's ear canal with their custom earmold (hopefully, or a foam tip) deliver the signal to the ear (same signal as was presented into the coupler)
- An SPL will again be measured (the child's real-ear unaided response)
- The real-ear system makes the calculation

Steps needed to collect real ear data in infants:

- The difference between the real-ear and coupler response is the RECD (It will also be a curve on your screen)
- The value is added to the hearing aid response measured in the coupler to predict the real-ear response

Steps needed to collect real ear data in infants:

- Choose your prescriptive formula (which will use the measured RECD to produce targets)
- The child's age in months need not be entered if you are measuring the RECD; this function (with DSL v. 5.0) is used only if an average RECD is chosen (which is not encouraged)

RECD Clinical Use

- Improve accuracy of some manufacturer "first fit"
- Only requires cooperation for one measurement rather than multiple REM
- Prescription can be verified in coupler w/o child present
- More effective use of clinic appt. time

RECD

- Positive RECD values indicate the extent to which levels measured in the real ear exceed levels measured in the coupler
- The smaller the ear canal (i.e., the younger the child), the greater the SPL measured at the TM and hence the greater the RECD

RECD

- RECDs have large individual variability, regardless of age
- Foam ear tip and earmold RECDs have very different shapes and are not interchangeable
  - the RECD values obtained with an eartip are approximately 5 dB greater in the high frequencies than are RECDs measured with the child's earmold

RECD

- Some "Pointers"
  - RECD can be performed while infant "sedated" or asleep for ABR
  - Use a mirror so older child can see what is happening (a partner helps)
  - Use "oto-ease"
  - Use a Comply Wrap
  - Wrap the probe tube and the earmold or tip together with plastic wrap and then insert together

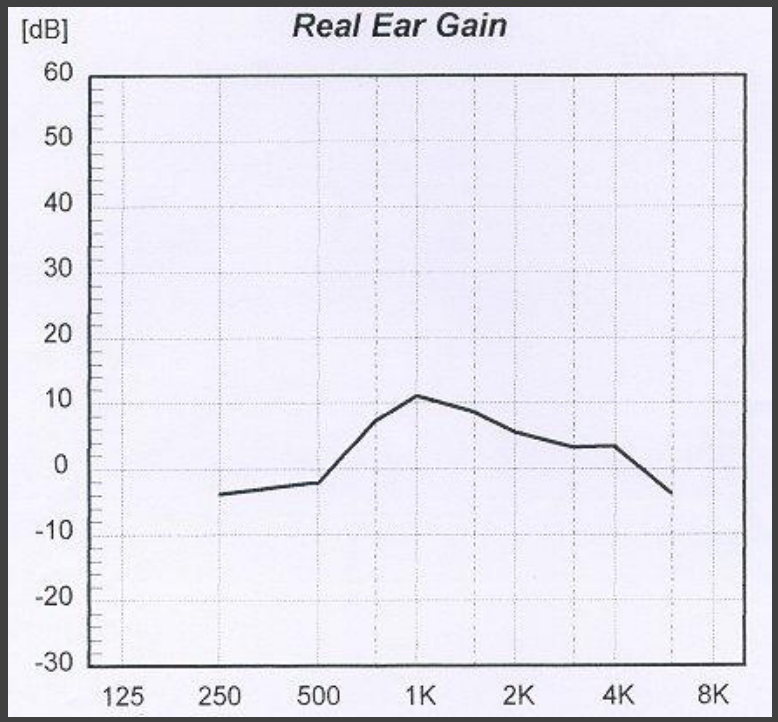
More Pointers - RECD

- Insertion depth of probe tube should be about 11 mm from the ear canal opening
- Always try to use the patient's own earmold; when a new earmold is made, RECD should be measured again
- If you cannot get the RECD for both ears, one ear is usually a good predictor for the other ear and preferable to using "average" RECD
- The cord from the probe microphone should be clipped on the child's opposite shoulder so the microphone lies snugly against the child's cheek and moves less.

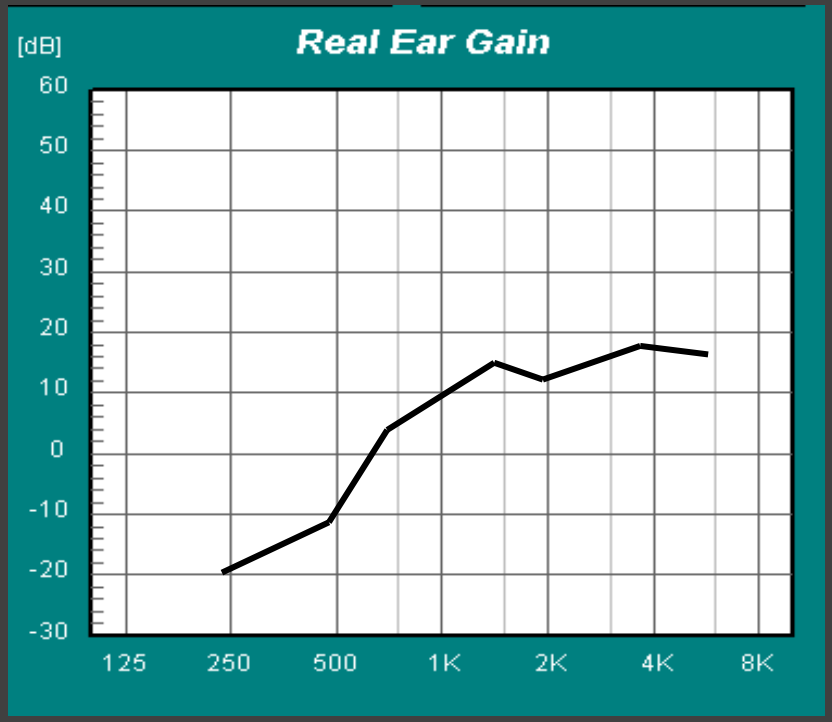
RECD

- If there is a "roll-off" in the low frequencies of –1 to –5 dB on the RECD, it usually indicates there is a slit leak, a vent larger than 1 mm or that the earmold tubing has hardened
- If the roll-off is large in the low frequencies (-10dB or greater), there can be a perforation or PE Tube
- Increased positive values in the low and mid-frequencies can mean MEE

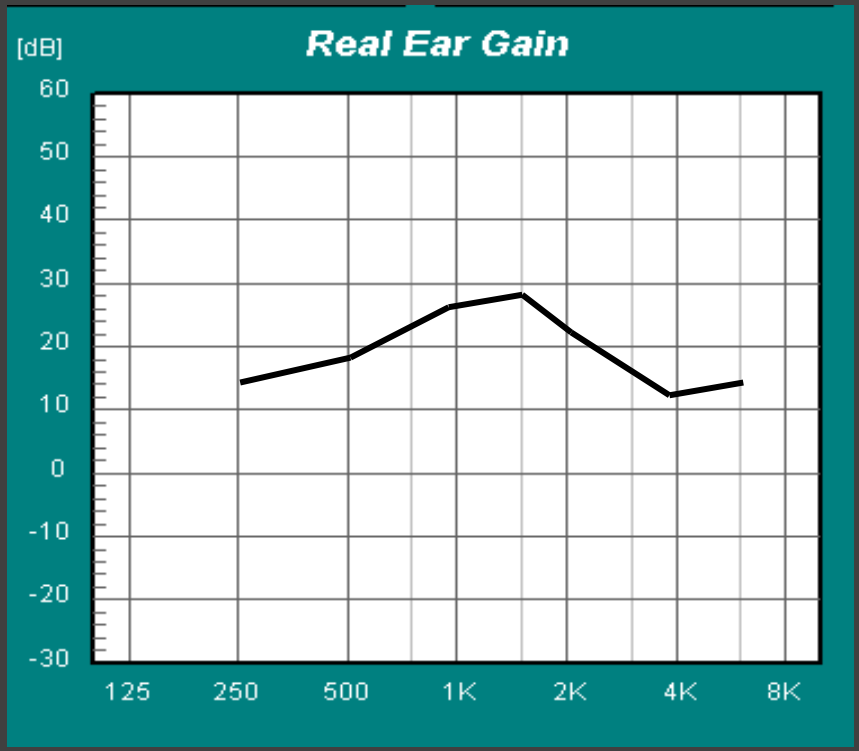
Leakage



Perforation or PE Tube



Middle Ear Effusion



Demonstration

- Demonstration slides to follow!

New Version of Desired Sensation Level (DSL)

- New version of DSL released very recently called DSL m{i/o}
- The "m" stands for "multistage"
  - DSL has always been an i/o prescriptive method, but now the i/o plot has four stages
    - Expansion, linear, WDRC, and limiting

DSL

- What is it?
  - The DSL Method makes use of HL audiometric data and converts it to SPL at the eardrum (using the Real-Ear-To-Coupler-Difference (RECD) measurement)

DSL

- What is it?
  - Like other prescriptive measures, the goal is to select hearing aid frequency and gain characteristics that place as much as possible of the long-term speech spectrum (LTASS) into the amplified range

DSL

- Still pediatric amplification focused
- Uses the RECD to predict REAR (still)
- Employs three age ranges
  - Infants, children, adults
- Two age types
  - Pediatric/congenital
  - Adult/acquired

DSL

- New version prescribes a higher level of gain and output in the pediatric/congenital prescription than in the adult/acquired prescription (about 7 dB for flat 50 dB HL audiogram)
- Adult prescription has less gain and slightly lower compression ratio
- Result is that DSL adult targets are about 10 dB lower for mild losses and gradually move closer to the children's targets as hearing loss increases

DSL

- New version takes into consideration method in which infants are identified (i.e., ABR)
- New version has specific corrections built in – the tone-ABR thresholds can be corrected from nHL to HL values, and there are new RECD norms that change in age by months

DSL

- New RECD norms extend through childhood by age in months, which provides a more "detailed look at the RECD than previously available"
- Also has new norms for earmold RECD (previously only foam tip norms available)

DSL

- New version has four different prescriptions
  - Kids in quiet
  - Kids in noise
  - Adults in quiet
  - Adults in noise

NAL-NAL2

- Takes into consideration
  - Dead regions of the cochlea
  - Age
  - Gender
  - Cognitive ability
  - Frequency selectivity
  - Experience with amplification
- Higher overall gain for children than adults

NAL-NAL2

- NALNALNL2 will provide gender--and experience--specific gain, prescribing 4 dB more gain for male experienced users than for female new users-

NAL-NAL2

- Keep maximizing speech intelligibility rationale
- Change the intelligibility modelling
- Prescribe less gain for adults, but more gain for children
- Increase the CR for adults and children with mild and moderate hearing loss, while restricting the CR for those with severe/profound hearing loss
- Introduce gain adaptation for new hearing aid users, and a gender effect

NAL-NAL2

- Research has shown that NAL-NL1 prescribes slightly too much gain
- Consequently, what you will see in NAL-NL2 is a reduction of gain of about 4 dB at some levels and probably a slightly bigger reduction at high input levels

NAL-NAL2

- Creators of NAL-NL2 end up with a higher gain for children than adults (like DSL)

NAL-NL1

- "NAL-NL1 aims to maximize calculated speech intelligibility while keeping the overall loudness of sounds at normal or less than normal levels."
- This is still the goal of NAL-NL2

Selection of HA

- During the selection process, a determination of appropriate circuitry and processing schemes should be based on the degree, configuration, and type of hearing impairment as well as consideration of familial and economic factors

Selection of HA

- Minimally, the fitting method employed to determine hearing instrument electroacoustic characteristics should be *audibility based* (not cosmetically based) with the goal to provide audibility of an appropriate amplified long-term average speech spectrum (LTASS)

Selection of HA

- Advances in technology have made it easier to manage the pediatric population with the use of amplification
  - Multi-band wide dynamic range compression
  - Automatic adjustment of response characteristics to acoustic environments
- Supported by experimental evidence

Hearing aid selection for children: consider the following

- Direct audio input.
  - FM systems should be considered when the child becomes older and more mobile and needs to listen from greater distances
  - FM technology is the system of choice to improve SNR (signal-to-noise ratio)
  - Most hearing aid companies offer an FM compatible boot for their hearing aids.

Selection

- Directional microphones should be considered for older children to improve SNR when FM technology is not being used.
  - Very young children need to hear environmental noise and distant speech from all directions to maximize language and speech development
  - Directional microphones are NOT recommended for very young children

Selection

- Tele-Coil (T) for telephone usage and microphone-telecoil (M-T) switching option, and direct audio input (DAI)
- Safety features-tamper resistant battery compartment and volume control covers

Selection

- Compression
  - Also known as non-linear amplification, should be used by child, particularly those too young to operate a VC
  - Gain is increased for lower level sounds (hopefully increasing intelligibility) and decreased for higher level sounds (increasing comfort and safety)
  - Gains prescribed by NAL-NL1 and DSL i/o inherently contain compression

Selection

- Noise Reduction or Speech Enhancement
  - Work by reducing the gain in a frequency region when the SNR is poorer than in other frequency regions or than some pre-set criterion

Selection

- Feedback Management and Canceling should be put on HAs for all children
  - In older children for whom listening to music is important, they should be able to turn off feedback cancellation and use feedback management instead (many feedback cancellations mistake sustained musical notes as feedback oscillation)

Selection

- Flexibility in setting the electroacoustic parameters of the hearing aid is essential.
  - Advanced technology (digital and digitally programmable) hearing aids and the use of multiple channels should be considered when the audiometric configuration requires gain or output modifications in specific frequency regions

Selection

- Behind-the-ear hearing aids are the style of choice for most children.
  - In-the ear hearing aids are not generally recommended for infants and young children due to their small ear canal sizes and rapid growth of the outer ear

Selection

- Binaural amplification should always be provided to young children with binaural hearing loss unless there is a medical contraindication.

Verification

- Verification has really taken place throughout the selection and fitting process
- The electroacoustic performance of the instrument should be matched to the prescribed 2cc coupler target values for gain and output limiting where the 2cc coupler values have been derived using an individualized real ear to 2 cc coupler transform (I.e., RECD)

Validation

- Validation of aided auditory function is a demonstration of the benefits and limitations of aided hearing abilities and begins immediately after the fitting and verification of amplification

Validation Measurement Options

- Behavioral
  - Sound field Aided Thresholds
- Objective measures of speech perception
- Subjective questionnaires

Validation

- Functional Gain
  - Has limitations and is not "…the preferred procedure for verifying electroacoustic characteristics of hearing instruments in infants and children…"
- BUT…

Validation

- Functional Gain
  - REM and functional gain (aided sound field measures) provide different (and important) information
  - They should be used together in the verification of non-linear hearing aids

Why This Process?

- Verification of a hearing aid
  - Ensure electroacoustic goals are met
- Validate hearing aid fitting
  - Determine impact of intervention
- Overall Goal
  - To see if impact of hearing loss has been reduced
  - That amplification goals have been addressed

Demonstration

- Step by Step
  - Calibrate
  - Enter Audiogram
  - RECD - measured and/or "average"
  - DSL – simulated (no person)

RECD

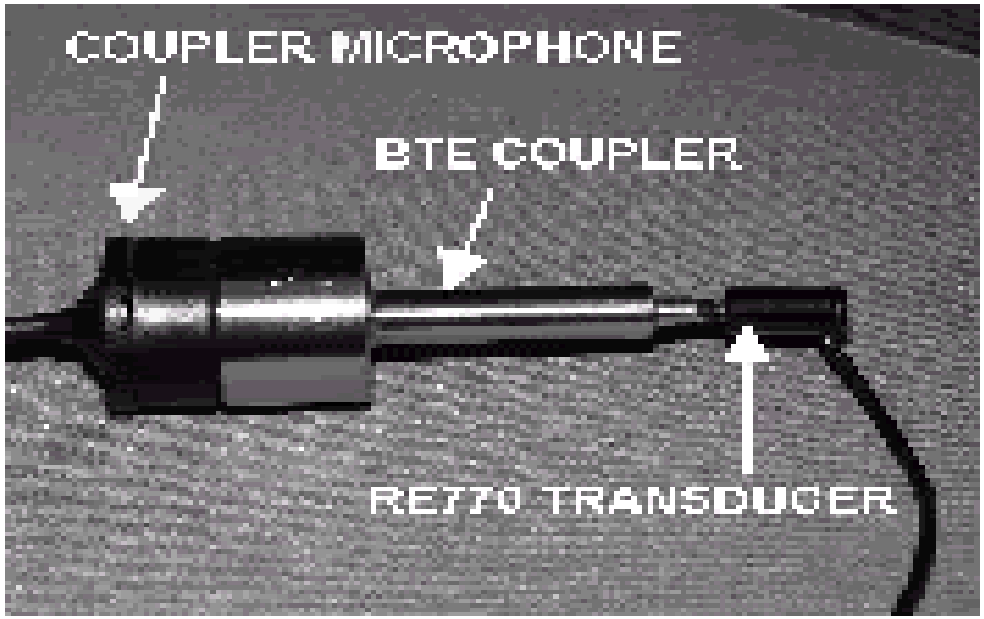


Figure 8. Setup for the coupler portion of the real-ear-to-coupler difference (RECD) measurement on the Audioscan RM500.

RECD

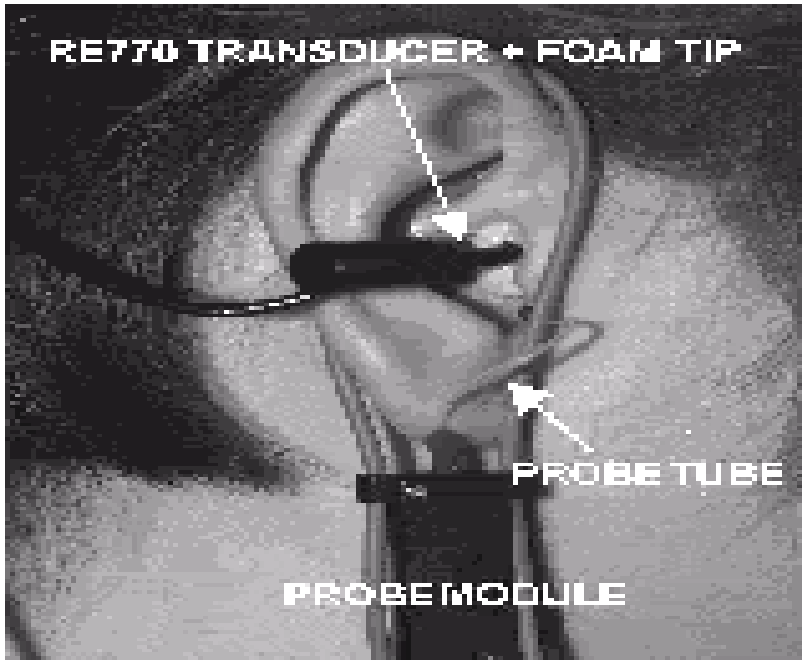


Figure 9. Setup for the real-ear portion of the real-ear-to-coupler difference (RECD) measurement on the Audioscan RM500.

RECD

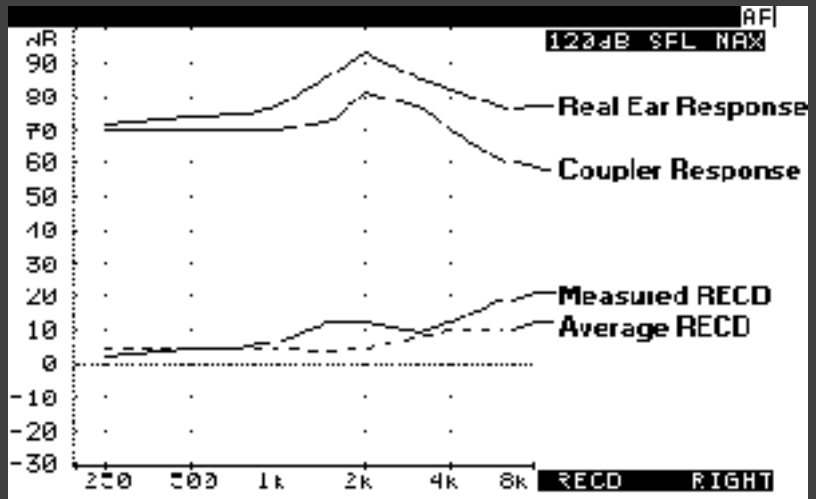
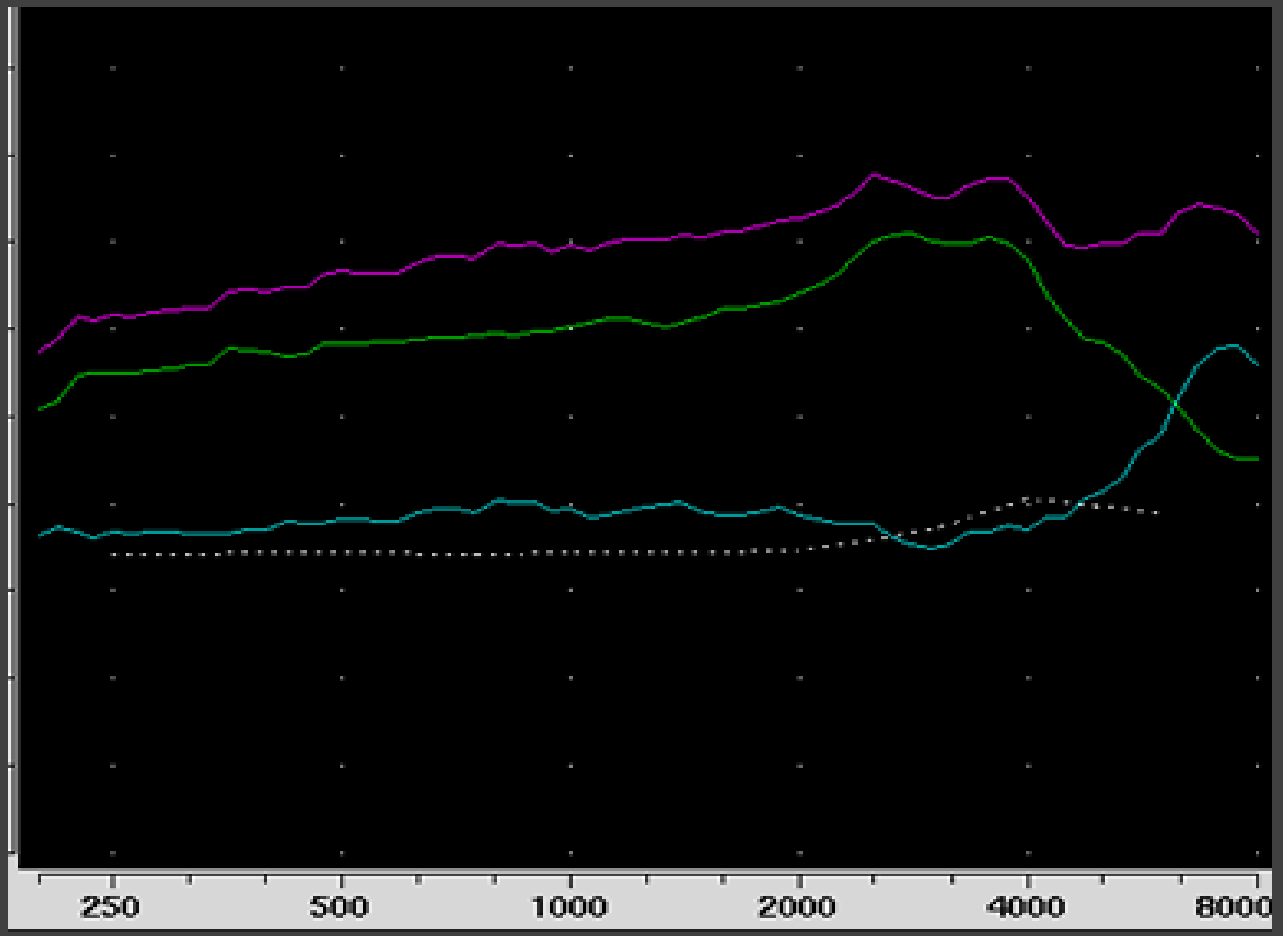
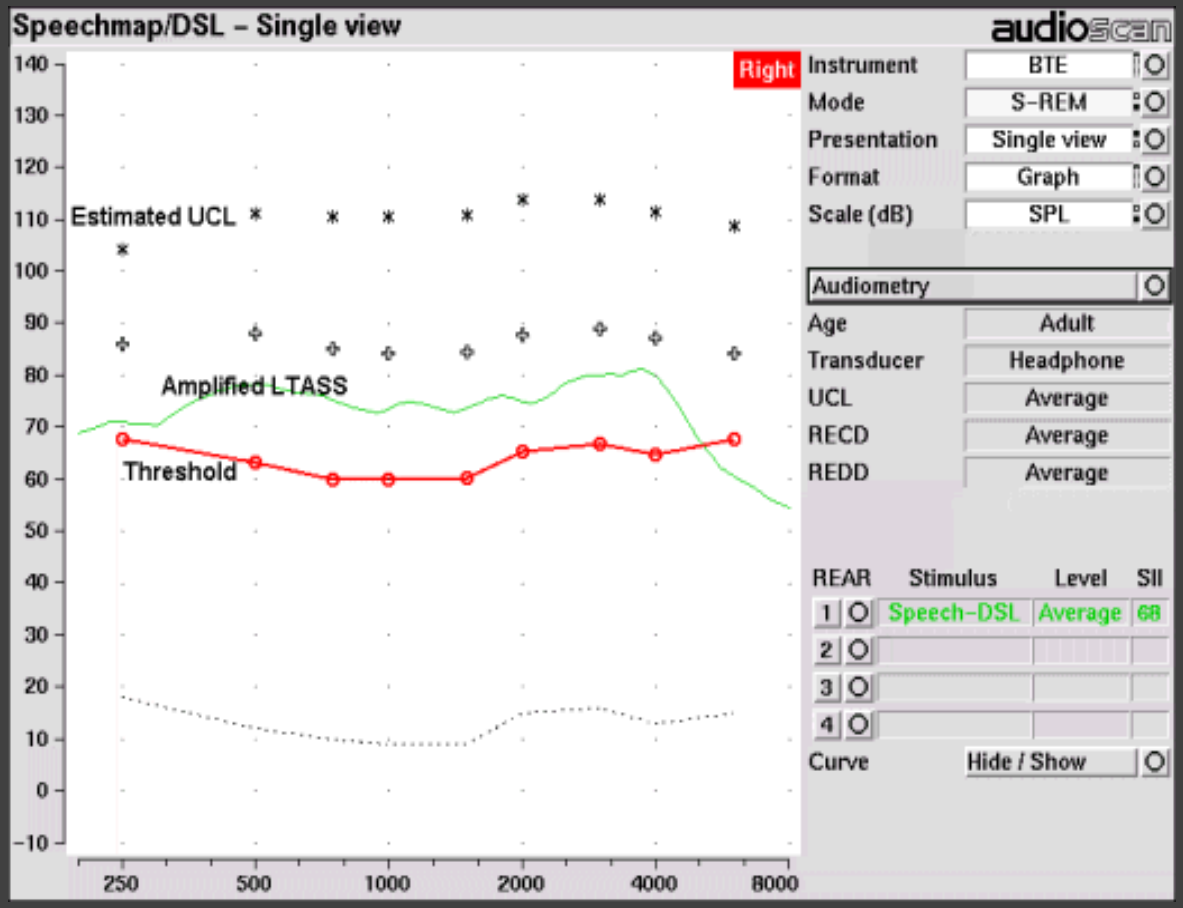


Figure 10. Example of the real-ear-to-coupler difference (RECD) measurement screen on the Audioscan RM500. The two curves at the upper portion of the screen represent the real-ear response and the coupler response, both measured using the same input signal. The two curves at the lower portion of the screen represent the measured RECD (difference between real-ear and coupler response curves) and the age-appropriate RECD (dotted line) for comparison purposes.

RECD



The Verifit VF-1 Real-Ear Measurement System



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Research Studies - 1

- DSL i/o and NAL-NL1
  - Children from Canada and Australia wore both prescriptive methods for 2 months
  - The average preferred gain by both groups was *between* the two prescriptions (higher gain than NAL-NL1 provided, lower gain than DSL provided)

Research Studies - 2

- Adults prescribed both responses
- Unanimous preference for NAL-NL1 method, driven strongly by DSL i/o prescriptive method judged as too loud

Research Studies - 3

- Ongoing research where infants were fit randomly with either NAL-NL1 or DSL i/o from their first fitting
- Preliminary data show no differences in *performance*

Research Studies

- Taken together, it appears as if congenitally impaired children prefer more gain than later impaired adults, but the differences in gain do not appear to result in any differences in performance

Research Studies - 4

- Followed 48 hearing impaired children over 8 months in a double blind study comparing DSL {i/o} and NAL-NL1

Research Studies - 4

- Results
  - -Very little difference for sentence recognition
  - -For soft or distant sounds (when you call me from another room in quiet) - DSL
  - -For noisy (restaurant, mall) - NAL-NL1
  - -Overall - kids from Canada preferred DSL, kids from Australia preferred NAL-NL1…we "like" and "prefer" what we know!

Research Studies - 4

- For soft and distant sounds, the additional gain DSL provides is preferred by most
- In noise, the lower gain in NAL sometimes is preferred