Marion Downs Lecture in Pediatric Audiology: A Retrospective on the Development of a Science-Based Approach to Pediatric Hearing-Aid Fitting – What a Difference 40 Years Can Make!
Recorded April 5, 2013

Presentation Outline

• Some Ancient History and Motivation for the Work
• Research and Development Process
• Current Research and Resources in 2013

Ancient History

A Guide to Newborn and Infant Hearing Screening Programs

Marion P. Downs and Graham M. Sterritt
Archives of Otolaryngology (1967)
Ancient History

1968

Behavioral Responses:
- Eye-blink (aural-palpebral reflex)
- Limb movement
- Whole-body response (Moro reflex)

Ancient History

1972-1976
Children’s Hospital, Halifax, Nova Scotia, Canada

Canadian Atlantic Provinces

What we had –
- Sound treated test booth
- Audiometer
- Impedance bridge
Ancient History

What we did not have –
- Auditory brainstem response measures
- Otoacoustic emission measures
- High-frequency tympanometry
- Hearing aid analyzer
- Real-ear measurement systems
- Hearing aid prescriptive procedures
- Cochlear implants
- Communication development programs for infants
- Parent information and support programs

The Comparative Hearing Aid Evaluation

ASSESSMENT

COMPARATIVE EVALUATION

SELECTION

The Audiometric-based Approach to Fitting (from Ling & Ling 1978)
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Mark Ross (1975)

6
Hearing Aid Selection for Preverbal Hearing-Impaired Children

For your hearing-aid client, do not over amplify or under amplify the auditory signals in the frequency range of 1,000 to 2,000 Hz. This is the range of frequency at which most children who are preverbal will be receiving the auditory information. If it is necessary to amplify this frequency range, be sure to do so in a way that is consistent with the amplification requirements of the other frequency ranges.

Mark Ross (1975)

Developing a New Pediatric Hearing Aid Fitting Method

Developing a New Pediatric Hearing Aid Fitting Method

Developing a New Pediatric Hearing Aid Fitting Method

Developing a New Pediatric Hearing Aid Fitting Method
Developing a pediatric hearing aid fitting method

1979
Goal: To develop a computer-assisted prescriptive procedure for the fitting of amplification in pre-verbal children.

Step 1
• Purchased a personal computer

Step 2
• Develop a new conceptual model of the hearing aid fitting process
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**Conceptual model of the fitting process**

1. ASSESSMENT
2. SELECTION / PRESCRIPTION
3. ELECTROACOUSTIC VERIFICATION
4. VALIDATION / ASSESSMENT

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**Step 3: How to define the variables**

- **Frequency in kHz**
- **SPLs**
- **HLs**

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**The Conventional Approach**

*Some Problems...*

All of the variables we are working with are not defined in the same way or at the same location.

- **SPLs**
- **HLs**
- **Audiologic Fruit Salad**
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The SPLogram from Erber (1979)

Questions, questions, questions . .

What is the best way to measure hearing for the purposes of hearing aid fitting in infants and young children?

Where do we want to place amplified speech within a child’s auditory area?

How do we know when the prescribed real-ear performance has been accomplished?

Step 4

Looked to the literature for studies of . .

• Speech perception and preferred listening levels in children
• Loudness discomfort and sensorineural hearing loss
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Speech perception (e.g., Erber & Witt 1977)

1980s: Algorithm Development

Developments in the 1980s:

Probe-Microphone Systems
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Target Aided Thresholds

Aided Audiogram with Prescriptive Targets

Real-ear prescription and measurement
Seewald, Ross and Stelmachowicz (1987)
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Real-ear prescription and measurement
Seewald, Ross and Stelmachowicz (1987)

1989

- Lab
- Computer
- Probe-microphone system
- Some funding
- Master clinician

The Fitting Process

ASSESSMENT

SELECTION

VERIFICATION

VALIDATION
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**Audiometric measures**

<table>
<thead>
<tr>
<th>dB HL</th>
<th>dB SPL</th>
</tr>
</thead>
</table>

**1990s**

- Gagné & Seewald studies (1991)
  Procedure for defining the auditory area of hearing impaired children: Detection thresholds and loudness discomfort level measures

Gagné & Seewald 1991
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The SPLogram: Thresholds in ear canal SPL

1990s
Moodie, Seewald and Sinclair
Procedure for Predicting Real-Ear Hearing Aid Performance in Young Children
American of Journal Audiology (1994)

Individualized Acoustic Transforms

Coupler Real-ear
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A sample of RECD values for infants

Bagatto, Seewald, Scollie and Tharpe
JAAA 2006

How well does this work???

Validation Studies

Predictive Validity of a Procedure for Pediatric Hearing Instrument Fitting

Seewald, Moodie, Sinclair & Scollie
American Journal of Audiology (1999)
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**Predictive validity of the RECD procedure**

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>300</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>4000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average unsigned error (dB)</td>
<td>1.9</td>
<td>1.7</td>
<td>1.5</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>95% CI (dB)</td>
<td>±2.0</td>
<td>±2.4</td>
<td>±2.4</td>
<td>±1.7</td>
<td>±2.2</td>
</tr>
</tbody>
</table>

CI = confidence interval.

Seewald, Moodie, Sinclair & Scollie

**Validity and Repeatability of Level-Independent HL to SPL Transforms**

Scollie, Seewald, Cornelisse & Jenstad
*Ear and Hearing* 1998

**Predicting Real-ear Thresholds** (insert phone / RECD)

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>4000</th>
</tr>
</thead>
<tbody>
<tr>
<td>95% Confidence Intervals</td>
<td>±6.8</td>
<td>±2.7</td>
<td>±2.6</td>
<td>±1.7</td>
<td>±3.6 dB</td>
</tr>
<tr>
<td>±3.5 dB for 95% of subjects across frequencies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From Scollie *et al.* *Ear and Hearing* (1998)
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The DSL Method uses the RECD to...

- Convert audiometric measures obtained using insert phones from dB HL to dB SPL in the ear canal
- Convert test box measurements of hearing instrument performance to estimate the real-ear performance of the hearing aid

Mid-1990s: Back to Development - DSL [i/o]

Cornelisse, Seewald and Jamieson
The Input / Output Formula:
A Theoretical Approach to Fitting Personal Amplification Devices

Fitting wide dynamic range compression instruments
Validation Studies

Preferred Listening Levels of Children Who Use Hearing Aids: Comparison to Prescriptive Targets

Scollie, Seewald, Moodie and Dekok
JAAA (2000)

Preferred Listening Levels in Children

PLL / DSL Comparison
On average, the DSL prescribed setting was 2 dB lower than the subject’s PLLs

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Comparison of Linear Gain and WDRC Hearing Aid Circuits: Aided Speech Perception Measures

Jenstad, Seewald, Cornelisse and Shantz
Ear and Hearing (1999)

Studies of Aided Speech Perception with DSL[io] algorithm

Jenstad et al. (1999) Ear and Hearing

Mean sentence perception scores were high (>90% correct) across a wide range of speech input levels (i.e., 48 – 63 dB SPL)

Studies of Aided Loudness with DSL[io] algorithm

Jenstad et al. (2000) Ear and Hearing

Aided growth of loudness was normalized for speech and other environmental sounds through the DSL[io] algorithm.
Technology transfer activities

Protocols and algorithms were transferred to most international manufacturers of hearing instruments and hearing instrument test systems

- More uniform implementation across clinics
- Use of the method by clinicians with relative ease

Clinical implementation
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Around 1999

- Question

With all that is available through manufacturer's software fitting systems, is there a need for another version of DSL?

A Question . . .

How similar are proprietary algorithms for fitting infants and young children?

Sample Findings

[Diagram showing sample findings]
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Sample Findings: Average Speech Input

- **21 dB Difference**

Sample Findings: Output Limiting Levels

- **133 dB SPL**
- **103 dB SPL**

~2000
Moved ahead with development of a new version

- Update RECD norms by age with emphasis on the infant population
- Solve the disconnect between ABR threshold estimates (nHL) and hearing aid prescription
- Better understand and define amplification preferences and requirements for children vs. adults
- Elaborate the DSU[io] algorithm to be compatible with emerging multichannel WDRC instruments
Updated Average RECD values

Real-Ear-to-Coupler Difference (RECD) Predictions as a Function of Age for Two Coupling Procedures

Bagatto, Scollie, Seewald, Moodie, & Hoover
2002, JAAA, vol 13(8)

ABR Threshold Estimation: in dB nHL

<table>
<thead>
<tr>
<th>ABR</th>
<th>500 Hz</th>
<th>60 dB nHL</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000 Hz</td>
<td>40 dB nHL</td>
<td></td>
</tr>
</tbody>
</table>

Can I use my tone-burst ABR results in nHL directly in hearing aid fitting?

Tone burst ABR measures for hearing aid fitting

Accuracy of Predicting Behavioral Thresholds from ABR Threshold Estimations in Real-Ear SPL

Bagatto, Seewald, Scollie, Liu, & Hyde
Trends in Amplification (2005)
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Summary of Results

- Average difference between ABR and behavioral thresholds was 5.6 dB
- Standard deviation ranged from ± 3 to ± 6
  - Reduced from previous studies

Conclusions

- When certain variables are considered, it is possible to use ABR threshold estimates to accurately predict behavioral thresholds in Real-ear SPL
  - nHL to eHL corrections
  - Ear canal acoustics
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Accounting for adult / child differences


Evaluating new adult fitting algorithm

The DSL v5 algorithm for adults fittings approximated the adult subjects PLLs to within 2.6 dB on average.


Provision of multi-level targets
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Provision of multi-level targets

DSL® v5.0a: The DSL Method for Fitting Modern DSP Hearing Instruments

Trends in Amplification, Vol. 9 (4) 2005

Research and Resources in 2013

• Research on Outcomes with Acoustic Amplification
• Clinical Protocols
• Practice Guidelines
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Research on outcomes with amplification

- Sininger, Grimes and Christensen (2010) Auditory development in early Amplified Children... Ear and Hearing
- Bagatto, Moodie et al. (2011) The University of Western Ontario audiological monitoring protocol (UWO PedAMP), Trends in Amplification
- Stiles, Bentler and McGregor (2012) The speech intelligibility index and pure-tone average as predictors... JSLHR
- McCreery, Bentler and Roush, The characteristics of hearing aid fittings in infants and young children, (in press, Ear and Hearing)

Brief summary of current research on outcomes

- Age of HA fitting is a significant predictor of outcomes
- Accuracy of hearing aid fitting (fit to targets) leads to greater audibility of speech (as predicted by the Speech Intelligibility Index [SII])
- Measuring the RECD improves fitting accuracy
- Greater audibility (SII) is significantly related to higher performance on outcome measures

Clinical protocols

Clinical protocols

British Columbia Canada

http://www.phsa.ca/AgenciesAndServices/Services/BCEarlyHearing/ForProfessionals/Resources/Protocols-Standards.htm

http://www.phsa.ca/AgenciesAndServices/Services/BCEarlyHearing/ForProfessionals/Resources/Training-Materials.htm

Practice guidelines

The American Academy of Audiology
Pediatric Amplification Guideline

Coming soon to your mailbox!

A very important outcome!
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What a difference 40 years can make
- Universal hearing screening programs
- ABR
- OAE
- ASSR
- High-frequency tympanometry
- Hearing aid analyzers
- Probe-microphone systems
- Hearing aid prescription procedures
- Hearing instrument technology
- Cochlear implants
- Parent information and support programs
- Well-trained and passionate professionals
- Early hearing and communication development programs
- A great deal more knowledge

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John Pumford
Susan Scollie
Jane Steinberg
Debra Zelisko

References
- McCreery, Bentler and Roush. The characteristics of hearing aid fittings in infants and young children, (in press, Ear and Hearing)