The Desired Sensation Level (DSL) Method

Early development . . .

1980
Goal: To develop a computer-assisted electroacoustic-based procedure for the fitting of amplification in pre-verbal children.

Early Development . . .

Looked to the literature for studies of . .
- Speech perception in children
- Preferred Listening levels and Loudness discomfort in children

History of the DSL Method

- Version 1 was completed in 1984 (pencil and paper)
- The first software system (DSL v3.0) was released in 1990 (DSL for fitting linear gain instruments)
- DSL[i/o] for Windows was released in 1996 (DSL[i/o] v4.0 for linear and WDRC instruments)
- DSL[i/o] v5.0 was released to hearing instrument manufacturers in 2005

Speech perception (e.g., Erber & Witt 1977)

Validation Studies

How well does this work???
Preferred Listening Levels of Children Who Use Hearing Aids: Comparison to Prescriptive Targets

Scollie, Seewald, Moodie and Dekok  
JAAA 2000

Funding provided by Phonak AG

### Preferred Listening Levels in Children

- **PLL / DSL Comparison**
  - On average, the DSL prescribed setting was 2 dB lower than the subject’s PLLs
  - The PLLs were within 5 dB of the DSL prescribed settings for 70% of subjects

### Preferred Listening Levels in Children

- **PLL / NAL Comparison**
  - On average, the NAL prescribed setting was 11 dB lower than the subject’s PLLs
  - The PLLs were within 5 dB of the NAL prescribed settings for 9% of the subjects
Studies of Aided Speech Perception and Loudness with DSL[i/o] algorithm

- Jenstad et al. (1999) Speech perception
- Jenstad et al. (2000) Aided loudness measures

Jenstad et al. (2000) Aided loudness measures:

Aided growth of loudness was normalized for speech and other environmental sounds through the DSL[i/o] algorithm.

DSL is just about right!

Different Prescriptions for Adults and Children

Background

Currently, there are currently differing opinions regarding the electroacoustic requirements for adults vs. children

- Prescriptive procedures developed for adults can be applied with young children (Ching, et al, 2001)
- Infants and young children require different prescriptive procedures (e.g., Stelmachowicz, 1991; 2000, Seewald et al. 1996).
Studies

- MacRae (1986)
- Snik & Hombergen (1993)
- Laurnagaray & Seewald (2005)

Relationships Between the Hearing Threshold Levels, Aided Threshold Levels and Aided Speech Discrimination of Severely and Profoundly Deaf Children

John MacRae
NAL Report No. 107
January 1986

MacRae (1986)

- Subjects: 100 children with moderate through profound hearing loss.
- Measured the real-ear gain they were using and compared this to that prescribed by the NAL-R algorithm
Hearing Aid Fitting of Preschool and Primary School Children

Snik and Hombergen
*Scandinavian Audiology* (1993)

- **Subjects:** 40 Adults; 60 Children
- Measured the preferred insertion gain as a function of the PTA hearing loss.

Snik and Hombergen (1993)

- The results showed that overall the mean use insertion gain was 7 dB less for the adults relative to that used by the children in this study.

**Procedure**

- **Subjects** (n=72)
  - 24 children who were full-time hearing aid users
  - 24 adults with experience wearing hearing aids
  - 24 adults who were new hearing aid users
- Prescriptive targets DSL[i/o] 4.1
- Participants had a variety of nonlinear hearing instruments
- New users provided with 15 to 20 day period of hearing instrument use

**Adult / Child Preferred Listening Levels**

Scollie, Seewald, Cornelisse, Moodie, Bagatto, Laurnagaray, Beaulac & Pumford
*Trends in Amplification* (2005)
Procedure

- Volume control wheel set to minimum
- Speech (RMS 60 dB SPL) via a loudspeaker in sound field
- Participant set VCW until talker sounded the best (repeated measure)

Adult/Child Preferred Listening Levels

- Repeated Measures:

  The average test-retest difference was 1 dB for all three groups and no participant varied by more than 6 dB on repeated measures.

The three groups differed in their PLLs:

- Children: The mean PLL was 2 dB below the DSL 4.1 target
- Experienced Adults: The mean PLL was 9 dB below the DSL 4.1 target
- New Adult Users: The mean PLL was 11 dB below the DSL 4.1 target

DSL® v5.0: Hearing Aid Prescription for Adults with Acquired Hearing Loss

DSL[i/o] 4.1 is too loud!
Preferred Listening Levels (PLLs) of Adults and Children Who Wear Hearing Aids Compared to DSL v5.0 Target Criteria

Seewald, Moodie, Scollie, Moodie & Polenko (200 ?)

Adult PLL / target comparisons study

• N = 9 adults with sensory hearing loss

• MEASURES:
  1. RECD measures
  2. Set hearing aid in S-REM using DSL v5 target criteria for REAR and RESR
  3. Set VCW to minimum, ask client to set to PLL using running conversational speech
  4. Measure S-REM at PLL setting
  5. Repeat
  6. Make desired electroacoustic changes per client report
  7. Measure S-REM of final setting
  8. Compare deviation from PLL

PLL / target comparisons

Average deviation from PLL 500 – 4000 Hz:
DSL 4.1 = 12.1 dB
DSL 5.0 = 0.5 dB

Implications for DSL v5.0

• DSL v5.0 acknowledges that adults and children not only require, but also prefer different listening levels, thus:

  Thus, DSL v5.0 is the first generic hearing instrument prescription algorithm to prescribe different sensation levels of amplified speech for children with congenital or early onset hearing loss versus adults with late onset hearing loss.
**DSL® v5.0: The New DSL Method for Hearing Instrument Fitting**

**The DSL Method v5.0**

- Compatibility with ABR Assessment Data
- Updated RECD Norms

**AUDIOMETRIC ASSESSMENT**

- The DSL m[i/o] Algorithm
- Multi-channel
- Targets for Quiet & Noise
- Modifications for Conductive Losses and Binaural Fittings
- Targets for Children & Adults

**ELECTROACOUSTIC PRESCRIPTION**

- Multi-Level Targets

**HEARING AID VERIFICATION**

---

**Compatibility with ABR Assessment Data**

- Diagnostic Audiologists correct ABR data by applying frequency-specific values
- Data reported in eHL on ISCIS form
- eHL data entered into DSL software for hearing aid fitting

**Application in DSL v5.0**

Three options:

- Enter *nHL* value and use DSL v5.0 default corrections
- Enter *nHL* value and use own correction values
- Enter *eHL* values – This assumes correction has already been applied
Updated RECD Predictions for Infants

Ontario Infant Hearing Program Corrections

<table>
<thead>
<tr>
<th>AC (dB)</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>4000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15</td>
<td>10</td>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>

*Equipment, parameter, and calibration specific

Updated Average RECD Values

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

Marlene Bagatto, Susan Scollie, Richard Seewald, Shane Moodie & Brenda Hoover
2002, JAAA, vol 13(6)
**Predicted RECDs**

DSL v4.1 predicted values:
- foam tip coupling only
- based on 12 month age ranges

Newly developed predictions:
- foam tip and earmold coupling
- to the nearest month

**Predicted RECD Values**

**Subjects**
- 392 infants & children
- ages 1 month to 16 years
- 141 ears used immittance tips
- 251 ears used earmolds
- normal otoscopic and immittance findings

**Results**
- high variability in RECD measures for children of the same age

**Limitations:**
- all subjects had normal middle ear function
- high variability in RECD measures associated with children of the same age

Therefore, whenever possible, predicted values should NOT replace the more precise RECD measurement.
Comparison of RECD Norms

New IHP Procedure

- If have DSL v5.0, use of the table of RECD values is no longer necessary
- Choose foam tip or earmold coupling
- Measured RECDs are always preferable

The DSL Method v5.0

- Compatibility with ABR Assessment Data
- Updated RECD Norms

ELECTROACOUSTIC PRESCRIPTION

- The DSL m[i/o] Algorithm
- Multi-channel
- Targets for Quiet & Noise
- Modifications for Conductive Losses and Binaural Fittings
- Targets for Children & Adults

The New DSL Multi-Stage Input-Output Algorithm

- Compatibility with ABR Assessment Data
- Updated RECD Norms

ELECTROACOUSTIC PRESCRIPTION

- The DSL m[i/o] Algorithm
- Multi-channel
- Targets for Quiet & Noise
- Modifications for Conductive Losses and Binaural Fittings
- Targets for Children & Adults

The DSLv5.0 m[i/o] algorithm:

- Expansion Stage
- Linear Stage
- WDRC Stage
- Limiting Stage

Targets for OUTPUT (dB SPL in the Ear Canal)
**The DSL m[i/o] algorithm**

![Graph showing the input range for WDRC](image)

**WDRC: Compression Threshold**

![Graph showing compression threshold](image)

**Working with Multichannel Hearing Aids**

![Diagram showing digital processing and multichannel compression](image)

**Modifications for Conductive Hearing Loss**

- Will increase the upper limit of comfort by 25% of the air-bone gap. Resulting targets are slightly more linear, and have slightly more gain.

- Targets are not allowed to exceed 140 dB SPL (ear canal).

---

**DSL 5.0: Binaural correction**

![Graph showing binaural correction targets](image)
Binaural Correction Notes

- The literature is not conclusive on whether a gain reduction is needed for binaural fittings in children. This element of DSL v5.0 requires further investigation. Until conclusive results are available, it is recommended that IHP associates choose ‘NO’ binaural correction even for those children fit with binaural aids.

MPO Targets

- The ULC target (**) is really intended to be matched by fully saturated hearing aid responses, therefore a slightly lower target may be more appropriate for use with the MPO test signal. For this reason, the target input/output function within DSL v5.0 can be used to compute a level-dependent target for either 85 dB SPL (in the real ear) or 90 dB SPL (in the coupler, using simulated real ear measurement). This new target will be somewhat lower than ULC for most hearing losses.
**Child Care Settings are Noisy Learning Environments**

- Noise levels in occupied preschool classrooms in child care centers can range from 66 to 94 dB(A).
- Noise levels in occupied infant/toddler classrooms range from 58 to 68 dB(A) and the SNR ranges from -3 to +12 dB.
- Up to 50% of young children in child care have chronic problems with fluid in their middle ear, where they experience this condition almost 50% of the time during the first 3 years of life.

**Seewald: Signal-to-Noise Considerations**

- If one believes in an auditory approach to speech and language development then the following must occur:
  1. The desired signal must be delivered within the child's residual hearing capacity.
  2. The speech signal must be perceived in order for the normal course and sequence of speech and language development to occur.
  3. The speech signal cannot be constantly buried in a background of noise.

**DSL v5: Prescriptions for Noisy Environments**

- Importance-based reduction in gain
  - Loudness comfort
  - Speech Intelligibility
- Derived from the Speech Intelligibility Index (ANSI, 1997)

**Prescription for Noisy Listening Environments**

- The Noisy Listening Environment targets require validation
- It is not a minimum implementation requirement for manufacturers in this release of DSL v5
- Many manufacturers, including Audioscan, have not implemented these noise targets in their first release of DSL v5

**Case Examples**
• Sample verification data for hearing aid fitting to DSL v5.0 targets.

Outcomes

• 100% vowel recognition
• 72% high frequency consonant recognition
• Loudness perception within normal range
• Real-world listening rated good to great on CHILD questionnaire

Evaluation of DSL v5.0

• 10 children – 7 to 17 yrs
• Mild to severe SNHL
• Binaural fittings – 55, 65, 75, MPO

Preliminary Data from Children

• 3 preferred responses slightly over target in low to mid frequencies
• 2 preferred responses slightly under target in low frequencies
• 5 satisfied with hearing aid set to target

Loudness Outcomes

• SII summarizes the proportion of audible speech
• SII in Verifit based on real-ear SPL thresholds and measured REAR of the aid
• Overall audibility present in the fitting as a percentage

DSL v5.0 and the SII
**DSL v5.0 and SII**

- SII value does not indicate the proportion of speech that will be understood by the user.
- Speech understanding depends on development, type of speech materials, listening environment, and other factors.

**What is a good SII?**

- SII has a level distortion factor that is applied for speech levels higher than 62.4 dB SPL.
- Applied in severe to profound fittings.
- Makes SII value appear lower than one would expect.

**IHP Protocol Review**

- An individual with congenital hearing loss can be fit with DSL child targets regardless of age.
- Transducer is eHL.
- Measure RECDs or choose average.
- Binaural is set to NO.

**IHP Verification Review**

- 75 dB HL and better SII >60%.
- 80 dB HL and above SII 20 to 60%.

**IHP Verification Protocol**
DSL Website Update

• Total website redesign will begin in January 2007
• Goal for completion: Late Spring 2007
• Discussion: suggestions for website

Protocol Review

• Discussion re: challenges in clinical practice in following recommended IHP amplification protocol.