Pediatric Amplification Protocol
Evidence-based decisions in Signal Processing and Verification

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- Ruth Bentler
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- Cheryl DeConde Johnson

- Shane Moodie
- Todd Ricketts
- Anne Marie Tharpe
AAA PEDIATRIC AMPLIFICATION PROTOCOL

• Mix of evidence-based research and expert opinion

• [www.audiology.org](http://www.audiology.org)
Addressed 9 areas of practice

- Personnel Qualifications
- Candidacy
- Pre-Selection Issues and Procedures
- Circuitry-signal processing
- Hearing Instrument Selection/Fitting Considerations in Children
- Verification
- Hearing Instrument Orientation and Training
- Validation
- Follow-Up and Referral
Candidacy...“Amplification with hearing instruments should be considered...  

• ...for a child who demonstrates a significant hearing loss, including sensorineural, conductive, or mixed hearing loss of any degree. The duration and configuration will assist the audiologist in the decision to fit a child with personal hearing aids. Additional factors such as the child’s health, cognitive status, and functional needs also will influence the time-line of fitting hearing aids.”
Upfront Considerations

- Air vs bone conduction
- Style/ type/ spare
- Routing of the Signal
- Receiver type
- Bandwidth
- Earmold type
- Length/ vent
- Sound channel
- Mic type/ location
- Controls for fine-tuning
- Previous Experience
- Telephone Access
- Ability to couple to assistive listening devices
- Battery doors
- Volume Control
Guideline

• With children, it is frequently necessary to conduct fine-tuning of the hearing aids’ gain and output characteristics. The audiologist often has more flexibility in fine-tuning with programmable instruments than with potentiometers. Hearing abilities of babies continue to be defined as they mature and flexible hearing aids can be changed to reflect the new information obtained from the diagnostic procedures. A flexible hearing aid is cost-effective solution...
Circuitry – signal processing

• Although certain signal processing schemes require digital processing, the discussion here is only relevant to the strategies, not digital versus analog processing to implement those strategies...in some cases the desired signal processing scheme may require digital signal processing...The choice of appropriate features for each individual is paramount.
Basic Requirements

- Avoid distortion
- Frequency/output shaping to provide audibility based on an appropriate prescriptive method
- Ensure audibility over a range of typical speech sounds from soft to loud
- Compression output limiting
- Sufficient electroacoustic flexibility to allow for changes in required frequency/output characteristics related to growth of the child (changes in RECD)
Current and Future Processing Schemes

• Automatic feedback control, be cautious about gain reduction schemes
• Multiple channels
  - Unusual or fluctuating audiograms
  - Application of WDRC
  - Increasing specificity of noise reduction
  - Specialized feedback and occlusion management
• Expansion to reduce low-level noise (typically microphone noise)
• Frequency transposition and frequency compression – only when signal cannot be made audible with non-transposing aids
Pediatric Amplification Guidelines

- Where might there be evidence?
  - Signal Processing in the dynamic range
  - Audibility/Verification
Level of evidence that we accepted in each area

- Randomized controlled trial (RCT)
- Non randomized controlled trial
- Cohort
- Before/After Design with control group
Systematic Search Strategy

- Group supplied known author names
- MEDLINE (1996 to present)
- CINAHL (1982 to present)
- Searched institutions that showed up in the above citations
- Searched the identified authors and institutions in the MEDLINE in-process and other Non-Indexed citations file
- Author search in EMBASE
- Subject heading and key word search in MEDLINE (1966 present)
- Hand searched book chapters. Lewis in Valente’s edited Treatment - Appendix A - Advanced Signal Processing Hearing Aids with Children
- Web of Science Cited references - what articles cited the target articles
- Related author search in PubMed for the Appendix A authors
- Contacted Patricia Stelmachowicz and Richard Seewald directly for their input
Key words

- Child, pediatric
- Hearing-impaired, hard of hearing, hearing loss
- Linear, WDRC, signal processing, microphone
- Language, speech, understanding, speech intelligibility
- Audibility, word recognition, discrimination
WHAT EBR IS AVAILABLE REGARDING SIGNAL PROCESSING in the Dynamic Range?

• Identified 5 studies that met our criteria level, but...
Are they little adults?

• The question really is: Are children’s amplification requirements different from adults?
• If they are different, we would have to consider that difference in prescribing real-ear gain and frequency response and therefore signal processing and as a result in our verification techniques.
Known differences

• Amount of audiological information we have to work with
• Present with a variety of configurations (Pittmann and Stelmachowicz, 2003)
• Present with more and larger asymmetries (Pittman and Stelmachowicz, 2003)
• Physical size of the ear canal (therefore RECD to correct thresholds measured in HL and to prescribe coupler response)
• Changing size
• May need to pre-set and verify exclusively in a coupler
• They won’t always give you an opinion (feedback) so you need to take the time to be correct
What they did

• Tested 60 normal hearing children, 23 hearing-impaired children (5-10 years old), and 20 normal hearing adults (18-35 years old)

• SPL and AI required to achieve 70% on a high and low predictability sentence test
What they found

• Children require higher AI and SPLs to achieve adult performance.
• Hearing aid gain is needed most for low-level inputs.
Just how important is audibility?

Goal

• Determine the accuracy with which hearing-impaired children can detect inflectional morphemes /s/ and /z/ when listening through hearing aids.
What they did

- Test development (36 normal hearing children)
- 40 hearing-impaired children (5 to 13 years old) with a wide range of hearing losses using hearing aids fit to DSL 4.1 identified nouns with plural forms spoken by a male and female talker
What they found

- Significant effect for talker (female worse)
- Significant effect for factor (plural words worse)
- The effect was not found for normal hearing children
- For the male talker, needed audibility between 2000 - 4000 Hz
- For the female talker, needed audibility between 2000 - 8000 Hz.

- The main goal of providing amplification for children is to ensure that they will receive full-time and consistent audibility of the speech signal at safe and comfortable listening levels.

- Remember full-time and consistent
Wide Dynamic Range Compression

• Theoretically… “reduces the long-term level variations of speech thereby maintaining audibility for soft speech, together with comfort for loud sounds, without the need for volume control adjustment”

» Byrne, 1996

Their goal...

- To test the theoretical advantages of single channel WDRC over a linear gain circuit for speech intelligibility, loudness comfort, and increased dynamic range.
What they did

• Tested speech intelligibility (nonsense words and HINT) and comfort across five speech spectra (levels) with 12 adolescent and young adults (mean age of 16) with three hearing aid conditions (unaided, linear, and WDRC).
• Fit to DSL targets using RECD, same hearing aid for both conditions.
• Moderate to severe SNHL, prelingual
What they found

• Linear and WDRC improved speech intelligibility relative to unaided
• Linear and WDRC performed similarly for average speech, but WDRC performed better for softer speech and shouted speech.
Goal

• To develop speech materials that would be sensitive to changes in speech perception by younger children when using different signal-processing strategies and to examine the effectiveness of WDRC for children with different degrees of hearing loss (including severe to profound) using these speech materials.
What they did

- 14 children with different degrees of SNHL aged 4 to 14 were fit bilaterally with hearing aids that could be programmed as single channel linear with peak clipping or WDRC circuits. The children participated in an open-set and closed-set word recognition task at three presentation levels (45 to 60) in quiet and noise.
What they found

• Closed set could be used with all groups tested and gave consistent results.
• Results indicated marginal significant benefits of WDRC over linear amplification.
• Weakness – response was matched to current aid – no measure of audibility.
Remember

• If the goal is full time and consistent without the need for VC adjustment, then WDRC makes sense based on simple acoustics (it is changing automatically).

• The concern would be that the compression impacts the acoustic cues in the signal in a negative manner - so findings of no difference compared to linear fittings would be considered a positive finding for WDRC.
So...

- Signal processing schemes that have been found to be beneficial with moderate-to-severely hearing-impaired pediatric patients:
  - 1.3:1 to 2:1 compression ratio
  - \(<50\) dB compression threshold
  - 10 msec attack time
  - 13 dB more gain for quiet inputs compared to adults
  - Wide bandwidth (8000 Hz)
  - Release time varied between studies
What does all this say about verification?

• If audibility is important, it should be verified in a manner that is appropriate to infants and children who cannot necessarily provide you with an accurate opinion about the signal and with all of this evidence in mind.

• The evidence base moves to acoustic facts.
Verify that soft, moderate, and loud sounds are audible and comfortable.

- In order to know if sounds are theoretically audible/comfortable – need to measure in the real ear and compare to threshold and UCL that if not measured in SPL have been transformed from HL to SPL taking into account the much smaller ear (RECD).
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<td>CRU 3</td>
<td>90</td>
<td>SHORT</td>
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**STATUS**
- BURST
- SWEEP TYPE SHORT
- NOISE RED 4X
- REFERENCE MIC OFF
- SMOOTHING
- LOG
- UNLEVELED
- COMPR THRES 40 dB
- RMS SOURCE 90 dB

**OUTPUT**

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<td>60</td>
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**U, A, T**

**TARGET**

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• Whether we are pre-setting in a coupler or verifying in the real ear, it becomes essential that the threshold and UCL data are accurate.
• We are basing our entire fitting on these data.
• Let’s go through an example...
One year old in 1998
NAME ______________________ M/F AGE _______ DATE ________

COMPLAINT/PURPOSE

TEST RELIABILITY E E G F F I AUDIOMETER ________ CALIBRATED ________ LAST TEST ________

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PRA - Mask LE Mask

1998

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HEARING AID

ACCUSTIC REFLEX THRESHOLDS

Stimulus Contralateral Ipsilateral

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Notes/Other Results:

Summary:

Recommendations:
EPR 4 y/o

GPR 1 y/ o

EPR 4 y/ o

MPM 5 y/ o
Individual, Predicted, and Adult Values for Threshold and UCL

Threshold in SPL at one year
UL in SPL at one year
Predicted threshold in SPL at one year
Predicted UL in SPL at one year
Predicted threshold in SPL for Adult
Predicted UL in SPL for Adult

Frequency (Hz)

dB SPL
• This is not only a fitting issue at one moment in time, but a diagnostic and counseling issue as well as a hearing aid feature selection issue.
2004, 6 years old
RECD over Time

RECD at one year

RECD at 6
In conclusion, there is evidence to suggest that:

- Children are not little adults.
- Children need soft, moderate, and loud sounds to be audible in a consistent manner.
- There is signal processing available to produce audibility, comfort, and good sound quality at these levels.
- Verification is essential because of the ability or lack thereof for children to participate in fine tuning.
- There are verification techniques available to ensure that you have met your goals.
Follow-up appointments include

- Behavioral audiometric eval
- Assessment of communication abilities, needs, and demands
- Adjustment of amplification system based on updated info

- Electroacoustic eval
- Listening check
- Earmold fit check
- Periodic probe-mic
- Periodic functional measures
- Academic progress
- Cover for loss and damage
Thank you