Fitting digital instruments to infants and young children
High-tech communication solutions for children...

“Through technological advances it is now possible to identify, define and habilitate hearing loss in virtually every infant.”

Stelmachowicz et al. 1998
The benefits of technologically advanced solutions

- Multi-channel gain precision
- MPO Shaping Flexibility
- A choice of processing strategies
- High-frequency amplification
- Feedback management
- Solutions for hearing-in-noise
- Addressing children's changing needs over time
- Sophisticated fitting tools
Presentation overview...

- A choice of processing strategies children
- Sophisticated fitting tools for accurate fittings
- Hearing in noise
Presentation overview...

- A choice of processing strategies children
- Sophisticated fitting tools for accurate fittings
- Hearing in noise
A choice of processing strategies

- Is WDRC also suitable for children?
- Is candidacy related to degree of hearing loss?
- Is WDRC beneficial in noise?
- Do we need a choice of processing strategies in one hearing instrument?
Comparison WDRC and linear

Jenstad et al. 1999
Comparison WDRC and linear

- WDRC has potential applications in pediatric fittings (moderate to severe S/N losses)
- WDRC presents a broad range of inputs at comfortable listening levels
- Is WDRC candidacy related to degree and configuration of hearing loss?
A choice of processing strategies

"Amplification and Signal Processing for Children with Severe and Profound Hearing Loss"

By Dr. Josephine Marriage, Prof. Brian Moore, University of Cambridge, UK
Fact

For moderate hearing loss, benefit from wide dynamic range compression (WDRC)

Amount of gain from hearing aid is dependent on level of sound coming into hearing aid.

- Makes loudness perception closer to “normal”
- Gives better audibility for weak sounds
- Leading to better speech discrimination for mild and moderate HL in adults and older children
- Avoids discomfort from intense sounds
- Reduces upward spread of masking

Marriage and Moore, 2003
Question

For severe/profound hearing loss – smaller residual dynamic range of hearing, so higher compression ratios needed

- May reduce depth of modulation in speech
- May reduce intensity contrasts
- May increase distortion in timing signals

*These effects may offset benefits of audibility giving no benefit or worse performance for severe and profound HL*

Marriage and Moore, 2003
Earlier study (Marriage and Moore 2003, IJA)

Using speech testing measures with 14 children:

- Benefit for children with moderate and severe hearing loss from WDRC amplification
- No significant benefit for profound hearing loss though trend towards improvement
- No acclimatisation time allowed to get used to the novel speech information

Therefore further study undertaken
Study aim: to assess benefit of WDRC for children with severe and profound HL

17 children (4 – 15 yrs) in two groups:

- 8 “severe” (PTA 60-85 dB HL)
- 9 “profound” (PTA 86-115dB HL)

All subjects

- in auditory/oral mainstream education
- fulltime aid users
- no conductive HL overlay

Marriage and Moore, 2003
Study protocol

Balanced randomisation of 3 algorithms:
- Linear with peak clipping (PC)
- WDRC
- Linear with output compression (SC)

Supero 412's frequency response matched to DSL i/o prescription

At least one week of hearing aid use with each algorithm before testing speech discrimination

Marriage and Moore, 2003
Evaluation tools

Pre-recorded word tests

- Familiar monosyllables with (APT 1) and without pictures (OCJW – phonetically balanced)
- VCV nonsense syllables

Pre-recorded sentence tests

- Familiar phrases (CPT)
- Grammatically simple sentences (ASLs), presented in noise with adaptive algorithm

Marriage and Moore, 2003
Stimulus Levels

**Profound Group:** (APT 1, CJW 1 and CPT)
80, 65 and 50 dB A in quiet

**Severe Group:** (APT 1, (or CCT) CJW 1, VCV and ASL)
Typically tested at:
45 dB A in quiet, 80 dB A in quiet
50 dB speech with 50 dB noise (0 dB s:n) or
50 dB speech with 45 dB noise (5 dB s:n)

*Different presentation levels for floor and ceiling effects*

Marriage and Moore, 2003
Results: Profound group, Closed set (p = 0.008) n=9

Marriage and Moore, 2003
Severe group, Closed set (NS) n=6

Severe group APT scores

<table>
<thead>
<tr>
<th>Number correct</th>
<th>45 in qt</th>
<th>50 in ns</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WDRC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Marriage and Moore, 2003
Profound group, Open set (NS) \( n=8 \)

Marriage and Moore, 2003
Severe group, Open set (NS) n=8

Severe group CJW scores

Marriage and Moore, 2003
Profound group, sentence test (NS)  
n=8

Marriage and Moore, 2003
Severe group, VCV and Sentence test

Severe Group nonsense word and sentence results

<table>
<thead>
<tr>
<th>% correct</th>
<th>VCV in qt</th>
<th>ASL in 60ns</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC</td>
<td>WDRC</td>
<td>SC</td>
</tr>
</tbody>
</table>

Marriage and Moore, 2003
What do the subjects think about the different amplification algorithms?

Profound
5 chose WDRC, 1 chose PC, 1 SC, 2 stopped

Severe
4 chose WDRC, 2 chose SC, 1 PC, 1 stopped

Marriage and Moore, 2003
Conclusions

- WDRC can improve consonant discrimination for profound extents of hearing loss
- No evidence of poorer performance associated with WDRC in severe or profound HL

We need to try using multi-channel compression hearing aids and evaluate the fitting with speech. Aided thresholds do not represent functional performance.

Marriage and Moore, 2003
And for younger children and babies?

- Work by Nittrouer indicates timing cues may be more important in speech recognition in normal hearing children up to age 2. Frequency cues may become more crucial from 2 years.

- If same is inferred for hearing impaired children: Use of linear fitting with early aiding for severe and profound hearing loss with real ear verification measures

- Change to WDRC as soon as possible

Marriage and Moore, 2003
Presentation overview...

- A choice of processing strategies children
- Sophisticated fitting tools for accurate fittings
- Hearing in noise
Sophisticated fitting tools

Gain and output -
How do I get the right dosage?
“A precise knowledge of the levels of sound we are delivering into the ears of a child is a fundamental responsibility”

Seewald 2002
The “right” fitting needs more than just the best hearing instrument...

under amplified  just right  over amplified
The Problem: performance in the coupler cannot predict performance in the ear
Levels in this 8 month old child’s ear peak at 147 dB!
The Solution - measure RECD

Real-ear levels - 2cc coupler levels = Real Ear to Coupler Difference
What is RECD?

- Difference between real ear response and coupler response
- Predicts real-ear hearing instrument performance
- Considers differences in ear canal shape and size
- Allows individualized calculation of gain and MPO values
Predicted RECD values –
We know that...

- RECDs in infants and toddlers differ significantly from average adult values
- RECDs vary from child to child even if they are the same age
- There is a weak, or no association between the measured RECD values and subject age
Predicted RECD values – We know that...

- Depending of frequency the actual different between measured and predicted RECD can be 10–14 dB!
- RECDs will change over time for a given infant
Predicted RECD Values

Bagatto et al 2002
Predicted RECD Values

![Graph showing RECD values versus age (months) at 500 Hz. The x-axis represents age in months, ranging from 0 to 120, and the y-axis represents RECD in dB, ranging from -15 to 25. The data points are scattered but show a slight trend towards lower RECD values with increasing age.]
So why doesn’t everybody measure RECD?

- Requires specialized equipment and training
- A lot of equipment and wires for small ears
A solution - RECD_{direct}

- An easy, fast and accurate method to include RECD in the fitting process
- Automatic integration of RECD values for gain and MPO pre-calculation
- Only one measurement needed
- Age group appropriate
Validation of $\text{RECD}_{\text{direct}}$

“Comparison of the fit to target with average RECDs and individually measured RECDs through real ear verification”

By Dr. Kevin Munro, University of Manchester, UK
Test protocol

- Fit to target with individually measured RECDs?
- 21 adults
- Supero 412, DSL[i/o]
- Precalculation with
  - Age-appropriate RECDs
  - Macoscan MH20
  - RECDdirect
- Real ear measurements verifying fit-to-target

Munro, 2004
Fit to target: Average RECDs

Munro, 2004
Fit to target: Audioscan-RECDs

INDIVIDUALLY MEASURED RECD (RM500 with ER3)

- ● ● = DSL target
- - = Average

Munro, 2004
Fit to target: with RECDdirect

PHONAK DIRECT RECD (SUPERO 412)

- = DSL target
- = Average

Munro, 2004
Conclusions

- Real ear verification: fit to target almost always +/- 5dB
- Deviations from target:
  Average RECDs > Audioscan > RECDdirect

“The best match was obtained using RECDdirect. This finding supports the use of RECDdirect in clinical practice”

Additionally – Andrea Bohnert (2003): University of Mainz, Germany

- RECDdirect results comparable to traditional RECD measurements
- Very high test-retest reliability
Presentation overview...

- A choice of processing strategies children
- Sophisticated fitting tools for accurate fittings
- Hearing in noise
Hearing in noise

- Hearing in competing noise is difficult for all
- Children with normal hearing are at a further disadvantage (Allen and Wightman, 1994, Nozza 1990)
- One of the main challenges for adults with S/N hearing impairment (Kochkin, 1994; Plomp, 1978)
- Young children with hearing impairment are at the greatest disadvantage
Hearing in Noise

"The situation of normal hearing listeners can be described as sitting comfortably on a branch, while the situation of special listeners is like hanging by one hand. Especially when the wind blows, hanging positions are less comfortable."

Nabélek & Nabélek, 1994
Infant speech sound discrimination in noise – normal hearing

- Children are at a greater disadvantage than adults
- Noise has greatest impact on children during the period of language acquisition

Nozza et al., 1990
Directional microphone advantage for adults – a recognized solution

Better

SNR for 50% [dB]

Claro omni  Claro fixed  Claro adaptive

* significant compared to fixed

Kühnel & Checkley 2000
Digital directional technology

Subject

dB SNR for 50% Correct

Better

Own hearing instrument

Claro P2

Condie et al. 2002

* significant
The effect of distance and noise on word recognition

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Word recognition in quiet close (1.8 m)</th>
<th>Word recognition in noise far (7 m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 years</td>
<td>88.3 %</td>
<td>67.0 %</td>
</tr>
<tr>
<td>5 years</td>
<td>94.3 %</td>
<td>84.0 %</td>
</tr>
<tr>
<td>6 years</td>
<td>98.0 %</td>
<td>86.7 %</td>
</tr>
<tr>
<td>Adults</td>
<td>99.3 %</td>
<td>97.0 %</td>
</tr>
</tbody>
</table>

Adapted from Johnson 1996
Beyond digital directional technology

- SRT in dB
- Normal
- FM Monaural
- FM Binaural

0° 45° 135° 225° 315°

TX3

1 m

Crandel & Valente, 2003
Noise affects learning - for everyone...

“Good classroom acoustics spares teachers and pupils the needless inefficiency of trying to go uphill with the brakes on”

(Hartmann, 1946)
But for children with learning difficulties noise affects learning even more...

- **Language-impaired children** show significantly more speech understanding difficulties compared to their normal peers (Stollman, 2003)

- Children with a **learning disability (LD)** have poorer overall speech-in-noise perception than normal children and are more adversely affected by a decreasing SNR (Bradlow, Kraus & Hayes, 2003)

- Children with an **Auditory Processing Disorder (APD)** experience difficulties comprehending spoken language in competing speech or background noise (Musiek & Chermak, 1997)

- Children with an **Attention Deficit/Hyperactivity Disorder (ADHD)** have difficulties following instructions (Keller, 1998)
How are these children managed?

Comprehensive management by a multidisciplinary team

- Direct remediation therapy
- Compensatory strategies
- Environmental modifications
Classrooms are noisy places

Reverberation

Background noise

Distance
For children with learning difficulties, environmental modifications are an absolute necessity.

Classroom acoustic design

Not sufficient on its own...

Use of an FM system

Considered a corner-stone intervention for most children with learning difficulties.
A new FM solution...

Transmitter

EduLink Receiver
Evidence shows a clear FM benefit for children with learning difficulties

- Increased attention
- Optimal spoken language understanding
- Higher academic achievement
- More consistent on-task behavior
- Maximum speech understanding in noise
- Improvement in classroom behavior

(Blake et al., 1991; Musiek & Chermak, 1997; Stach et al., 1987; Crandell et al., 2002)
Technologically advanced solutions
– In conclusion

- Excellent sound quality through sophisticated processing
- Precision and flexibility through multi-channel gain amplification
- Maximal use of residual hearing
- Better high frequency amplification
- Advanced solutions for hearing in noise – for hearing and hearing-impaired children
- Unrivalled flexibility to address changing needs over time
- Sophisticated fitting tools
THANK YOU!