Prescribing hearing aids for adults and children

**Infant Fitting Procedure**

- Electrophysiological hearing threshold with insert phones (dB nHL)
- Behavioural hearing threshold with insert phones (dB HL)
- Measure individual RECD, (or estimate RECD from age)
- Calculate hearing threshold level (adult equivalent dB HL or dB SPL in ear canal)
- Apply prescription to derive coupler gain targets
- Adjust hearing aid via coupler/programmer to achieve coupler gain targets
- Verification of NEAG?
- Evaluation!

**Prescribe hearing aids to:**

- Make speech intelligible
- Make loudness comfortable
- Prescription affected by other things:
  - localization,
  - tonal quality,
  - detection of environmental sounds,
  - naturalness.

**The rationale for NAL procedures**

Maximize calculated speech intelligibility, but
Keep total loudness less than or equal to normal

NAL-NL1 (1999) → empirical studies
→ psychoacoustic studies
→ speech intelligibility models → NAL-NL2

**Deriving optimal gains - step 1**

- Speech spectrum & level
- Loudness model
- Normal loudness

- Gain-frequency response
- Compare
- Intelligibility achieved
- Amplified speech spectrum
- Loudness model
- Loudness (hearing impaired)
Overall approach to prescription

Psychoacoustics
Assumptions, rationale
Speech science
Theoretical predictions
Final formula

Empirical observations

Calculating loudness

Loudness model of Moore and Glasberg (2004)

Allowance for hearing loss

External & middle ear
Input to cochlea
Excitation level
Loudness per band

Free field speech level
Filtering into auditory bands

Calculating loudness

Sum across bands

Effect of language

- Gain at each frequency depends on importance of each frequency
- Low frequencies more important in tonal languages
- Two versions of NAL-NL2
  - Tonal languages
  - Non-tonal languages

Calculating loudness

1/3 octave SPL

Threshold

Noise

Audibility: ...

5

16

17

0

x

x

x

x

Importance: 0.001 0.002 0.003 0.002

= = = =

0.005 0.032 0.051 0...

0 = 0.30
**Speech Intelligibility Index**

\[ \text{SII} = \sum A_i I_i \]

Sum

**Audibility** **Importance**

But intelligibility gets worse if we make speech too loud!

**The transfer function**

![Transfer function graph](image)

**Observed and Predicted performance**

**Audibility and Speech intelligibility – H.I.**

![Observed and Predicted performance graph](image)

**Deficit = S_{ansi} - SII_{eff}**

Deficit = 0.6 - 0.4 = 0.2

![Deficit graph](image)

**Intelligibility and audibility**

![Intelligibility and audibility graph](image)
Psychoacoustics

Why measure only pure tone thresholds?

Other measurements

- Hearing threshold levels
- Outer hair cell function
  - click-evoked otoacoustic emissions
- Frequency resolution
  - psychophysical tuning curves
  - cochlear dead regions – TEN test
- Cognitive ability
- Age
Healthy PTC - no dead region

Poor PTC: Dead region at 4 kHz

Off-frequency listening: TEN test

Off-frequency listening: PTC

TEN and PTC (non) agreement

<table>
<thead>
<tr>
<th></th>
<th>TEN: Alive</th>
<th>TEN: Dead</th>
<th>TEN uncertain</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 kHz</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>PTC:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tip in place</td>
<td>60</td>
<td>1</td>
<td></td>
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<td>Tip shifted</td>
<td>4</td>
<td>3</td>
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<tr>
<td>PTC uncertain</td>
<td>1</td>
<td>2</td>
<td>1</td>
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</tbody>
</table>

Can we better predict intelligibility if we use psychoacoustic results?
Yes, a little - speech deficit increases as frequency selectivity gets broader

But not once we fully build HL into the SII prediction

Likely intermediate effects

Implications for prescription

Pure tone thresholds critical

Knowledge of temporal resolution, frequency resolution, dead regions adds relatively little to prediction of intelligibility

Age and cognitive ability affect all frequency bands similarly → no effect on gain needed

Why are hearing thresholds so useful?

Gain; adults, medium input level
(N = 187)

Gain preference over time

Source: Keidser, O'Brien, Yeend, & McLelland (submitted)

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Adjustments to prescription to allow for experience

Gain; adults, low and high input levels

Compression ratio preferences: severe and profound hearing loss

Binaural loudness correction

RECD in infants (own mold; HA2)

Directional microphones for infants and toddlers?

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Language at 12 months after fitting

- Effect of age of fitting: \( p = 0.0001^* \)
- Effect of prescription: \( p = 0.9 \)

<table>
<thead>
<tr>
<th>Fitting age category</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>110</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 6 mo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;= 6 mo</td>
<td></td>
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</tbody>
</table>

Covariate means:

- F6AV3FAMD: 55.64857

Language skills at 3 yrs

Effect of age of implant: \( p = 0.02 \)

Consonant perception at 55, 70, 80 dB

Effect of age of implant: \( p = 0.02 \)

Preference rating in real life

Intelligibility in noise

- Amplification / tone controls
- Feedback cancelling
- Auto-telecoil
- Rechargeable battery
- Alerting tones and messages

Intelligibility in quiet

- Phone interface
- Auto-telecoil
- Bilateral manual control
- Bilateral feedback control
- Bilateral auto control
- Bilateral expansion

Convenience

- Multi-program
- Directional microphones
- Adaptive noise suppression
- Open fittings
- Auto-program
- Data logging
- Auto-gain adaptation
- Trainability
- Auto-telecoil
- Phone interface
- Multi-program
- Directional microphones
- Adaptive noise suppression
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- Phone interface

Clinicians

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