DEVELOPMENT OF NAL-NL2

Harvey Dillon, Gitte Keidser, Teresa Ching, Matt Flax, Scott Brewer

The HEARing CRC & The National Acoustic Laboratories
Prescribe hearing aids to:

- Make speech intelligible
- Make loudness comfortable

- Prescription affected by other things
  - localization,
  - tonal quality,
  - detection of environmental sounds,
  - naturalness.
Deriving optimal gains - step 1

Speech spectrum & level → Gain-frequency response → Loudness model → Normal loudness

Intelligibility model

Amplified speech spectrum → Loudness model

Compare

Intelligibility achieved

Audiogram

Loudness (hearing impaired)
The audiograms

Rejection criterion:
- $-30 \leq G \leq 60$, where $G$ is the slope
- $\sum(H(f))/3 \leq 100$, where $f$ is in the set $\{0.5, 1, 2\}$ kHz

Inverted hearing loss profiles used
### Deriving optimal gains - step 1

<table>
<thead>
<tr>
<th>Audiogram 1</th>
<th>Speech level 1</th>
<th>Optimal gain frequency response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Audiogram 1</td>
<td>Speech level 2</td>
<td>Optimal gain frequency response</td>
</tr>
<tr>
<td>Audiogram 1</td>
<td>Speech level 3</td>
<td>Optimal gain frequency response</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Audiogram 2</th>
<th>Speech level 1</th>
<th>Optimal gain frequency response</th>
</tr>
</thead>
</table>

200 audiograms x 6 speech levels → 1200 gain–frequency responses, each at 20 frequencies from 125 Hz to 10 kHz
Overall prescription approach

Psychoacoustics

Assumptions, rationale

Speech science

Theoretical predictions

Empirical observations

Compare

Adjust

Final formula
Limiting compression ratio

The maximum C

$C_a$

$H$

$log_2 \left( \frac{f}{125} \right)$
Multi-dimensional equation

A neural network

\[
\begin{align*}
H_{250} & \rightarrow G_{250} \\
H_{500} & \rightarrow G_{500} \\
H_{1000} & \rightarrow G_{1000} \\
H_{2000} & \rightarrow G_{2000} \\
\cdots & \cdots \\
H_{8k} & \rightarrow G_{8k} \\
& \rightarrow \text{SPL}
\end{align*}
\]
The two key ingredients

- Speech spectrum & level
- Gain-frequency response
- Intelligibility achieved
- Amplified speech spectrum
- Loudness model
- Normal loudness
- Compare
- Loudness (hearing impaired)

Intelligibility model

Audiogram
Psychoacoustics
Why are hearing thresholds so useful?

- Frequency selectivity
- Temporal resolution
- Central auditory processing
- Speech perception proficiency
- Cognitive ability

Factors:
- Hearing thresholds
- Age
- Other
Factors affecting prescription
Gain; adults, medium input level

(N = 187)
Suggest that the compression ratio should be slightly higher, at least for clients with mild and moderate hearing loss.
Binaural loudness correction

![Graph showing gain variation (dB) vs. input level (dB). The graph indicates a linear increase in gain variation as the input level increases.]
Empirical evidence:
variations from NAL-NL1

Output level

Input level

Children
NAL-NL1
Adults
Adults – congenital or acquired?

Preferred gain deviation from NAL-RP (dB)

<table>
<thead>
<tr>
<th></th>
<th>LFA</th>
<th>HFA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Congenital</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(N=15)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Acquired</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(N=28)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

-14 -12 -10 -8 -6 -4 -2 0

-14 -12 -10 -8 -6 -4 -2 0
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
Tonal versus non-tonal language
Example audiogram: moderate sloping
Example audiogram: flat 60
Example audiogram: steeply sloping
Example audiogram: extreme ski-slope
Example audiogram: reverse sloping
Variables in NAL-NL2

Blue = User i/p  
Grey = internal variable  
Red = effect of saturation  
Dash-dot = alternatives  
Green = stored data
“A challenge for the profession is to devise fitting procedures that are scientifically defensible and the challenge for the individual audiologist is to choose the best procedures from whatever are available”

Denis Byrne, 1998
Thanks for listening

Acknowledgements

This research was financially supported by the HEARing CRC established and supported under the Australian Government’s Cooperative Research Centres Program

www.hearingcrc.org
www.nal.gov.au