How Speech Perception Measures Inform Amplification

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Phonak Sound Foundation

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Validation of amplification: means speech-based testing from HA fitting

Systematic and Methodical Observation:

• Functional responses to speech via habilitation team and family
• Types of speech material appropriate to dev level
• Different classes of speech sounds eg Ling
  – To fine-tune hearing aid fitting
  – To identify progress from previous assessment
  – To identify targets for listening work
Aims of presentation:

To demonstrate that testing is possible and necessary

Show crucial use of speech testing in individual cases
Speech Perception study: Rationale based on case-study
Speech perception study in 2 – 8 years
Rationale: comparison of HA fittings at different stages of speech acquisition

HA Prescription rationales
• eg Desired Sensation Level (DSLi/o, or version V)
• NAL-NL1
• CAMEQ

Ethics requires use of published prescriptions

Therefore study uses DSL and NAL to characterise different acoustic characteristics for hearing aid amplification

Need children with hearing loss from 2 to 8 years, perilingual to post-lingual stages of speech acquisition
How do NAL and DSL differ?
Considerations for new speech tests

**New outcome measures:** A range of new speech tests was developed.

(1) Three closed-set monosyllabic speech tests with pictures for different developmental levels. Pictures are presented on a touch sensitive screen or laptop with mouse.

(2) Ten open-set word lists for use in quiet and/or noise.

(3) Ling 5 pre-recorded stimuli (phonemes /u, a, i, sh s/).

**Norms for Speech Perception tests**
Thirty-six normally hearing (NH) children (2-8 years) norms. Minimum level for closed set in NH: 30 dB

Vocabulary screen (Renfrew) specifies speech test to use
What do we want to check?

Validation from *first fitting* using speech-based material

Necessary to know functional effect of HA fitting
- Detection of high frequency speech sounds
- Discrimination of vowels
- Discrimination between consonants
- Recognition of words
- Understand running speech
- Informal observation
- Opinion of child, including perception of noise floor

ALL CLASSES OF SPEECH SOUND ARE IMPORTANT
Age for formal speech testing?

- Clinician needs to have high expectations
- Trust in child to self-motivate if interesting feasible task
- Allow child autonomy to do the testing however they wish
- Maintain child’s self esteem
Detection of phonemes (3-8 years)

• Closed set detection task:
  eye, ice, lice, slice (/s/)
  pay, pace, space, face
  eye, wine, why, wise (/z/)
• Ling 5 (Ling 6 had /u/ /m/ confusions for NH)
  Repetition task: oo ar ee sh ss (pre-recorded)
Consonant discrimination

Closed set testing with four item picture task

• Age 2 – 4 years (40 items)
  Eg horse, fork, ball, door
  hen, peg, egg, bed

• 4 - 7 years (40 items or 60 items)
  Eg fat, cat, bat, mat (word-initial)
  cheese, cheat, cheap, cheek (word-final)

Derive confusion matrix of the errors
Significant difference if > 7.6% (10%) change in score, (s.d.=2.3)
Systematic use of speech tests

Presentation levels:
Level = 3 frequency PTA in better ear x 0.4 + 30 dB
Subject: female 4 years old

Closed set test
Take best ear 3 freq average: 57 dB x 0.4 = 22 dB
Add to NH level for test = 30 dB
Present at 52 dB
Subjects and test conditions

N=54 moderate and severe HI children

10 subjects dropped out from study

- Three age groups
  - Group 1 (2-3yrs) n=8
  - Group 2 (4-5yrs) n=14
  - Group 3 (6-9 yrs) n=22

- Study Hearing Aids: (Phonak Savia Art, Oticon Safran or Phonak Naida + 2 own aids)
- Fitted to match gain targets for NAL, DSL I/o and DSL v
- Verified with real-ear-to-coupler difference measures using real speech input with the Verifit REM system.
- Each of the 3 prescriptions was pre-programmed and stored under a blind code.
- Tester was blind to condition under test.
## Results:

Ling phoneme detection level (dB) for:

<table>
<thead>
<tr>
<th></th>
<th>DSL V</th>
<th>DSL [i/o]</th>
<th>NAL-NL1</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>/u/</td>
<td>47.4</td>
<td>48.1</td>
<td>50.0</td>
<td>0.018</td>
</tr>
<tr>
<td>/i/</td>
<td>46.7</td>
<td>47.4</td>
<td>49.0</td>
<td>0.019</td>
</tr>
<tr>
<td>/s/</td>
<td>51.1</td>
<td>51.3</td>
<td>56.2</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

No differences were found for /a/ and /sh/ detection levels.
Closed set computerised testing CAPT (2 – 8 years)

Closed set discrimination (%): $p < 0.001$ (cat, fat, mat, bat)

<table>
<thead>
<tr>
<th></th>
<th>DSL V</th>
<th>DSL [i/o]</th>
<th>NAL-NL1</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>80.1</td>
<td>81.8</td>
<td>74.1</td>
</tr>
</tbody>
</table>

Closed set phoneme detection (%): $p < 0.001$ (eye, ice, lice, slice)

<table>
<thead>
<tr>
<th></th>
<th>DSL V</th>
<th>DSL [i/o]</th>
<th>NAL-NL1</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>84.2</td>
<td>95.6</td>
<td>77.9</td>
</tr>
</tbody>
</table>

Closed set vowel in noise (%): $p = 0.32$ (NS)

<table>
<thead>
<tr>
<th></th>
<th>DSL V</th>
<th>DSL [i/o]</th>
<th>NAL-NL1</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>84.0</td>
<td>86.5</td>
<td>81.2</td>
</tr>
</tbody>
</table>
Open set words: list of 10 words, tested at 65 and 50 dB (4 – 8 years)

Open set word recognition with 65 dB presentation
No significant difference between prescriptions

Open set word recognition (50 dB) $p < 0.001$

<table>
<thead>
<tr>
<th></th>
<th>DSL V</th>
<th>DSL [i/o]</th>
<th>NAL-NL1</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>22.4</td>
<td>23.1</td>
<td>19.7 /30</td>
</tr>
</tbody>
</table>

Phrase testing (CPT) (dB) (adaptive pres) $p=0.001$

<table>
<thead>
<tr>
<th></th>
<th>DSL V</th>
<th>DSL [i/o]</th>
<th>NAL-NL1</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>39.4</td>
<td>38.8</td>
<td>41.5</td>
</tr>
</tbody>
</table>

CAWL words in noise $p = 0.055$

<table>
<thead>
<tr>
<th></th>
<th>DSL V</th>
<th>DSL [i/o]</th>
<th>NAL-NL1</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean</td>
<td>24.5</td>
<td>24.5</td>
<td>21.8 /30</td>
</tr>
</tbody>
</table>
Important points for speech testing:

• No significant difference in performance across different age groups (p=0.12), though small number of subjects in the younger groups.

• No significant order effects were found, although there was a trend for performance to improve with test familiarity.

• Only one child dropped out because couldn’t do testing (ASD)

Every decibel of the hearing aid fitting matters in optimising speech perception.
Must have systematic method for speech discrimination that identifies progress and next target for habilitation.
Case-study 1: Male 13yr

Aetiology: Meningitis at 9 months with some recovery
HA with open mould on right school only
Sometime doesn’t feel HA helps
Good speech
Reasonable academic progress
Cups ear to hear fast speech
45 dB presentation, all fittings matched to DSL V targets

<table>
<thead>
<tr>
<th>Unaided listening using both ears:</th>
<th>Hearing aid right: Masking noise to left</th>
<th>FCHearing aid right: Masking noise to left</th>
</tr>
</thead>
<tbody>
<tr>
<td>76% correct</td>
<td>71% correct</td>
<td>82% correct</td>
</tr>
<tr>
<td>Errors were:</td>
<td>Errors were:</td>
<td>Errors were:</td>
</tr>
<tr>
<td>Init: p/t, f/k, k/p, f/b</td>
<td>Init: sh/s, b/f/m, dr/j</td>
<td>Init: b/f, k/t, ch/t, t/f</td>
</tr>
<tr>
<td>Final: g/z, d/z, n/nothing</td>
<td>sh/f, k/t, f/t, f/ch</td>
<td>Final: n/nothin, n/z, t/k</td>
</tr>
<tr>
<td>Despite able to use left ear</td>
<td>FCHearing aid right</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Case study 2: 8 months female Known Unilateral Left HL via NHSP

• Aetiology investigations show widened vestibular aqueducts (WVAS) R and L

• Pendreds Syndrome screen negative

• ABR shows severe hearing loss right, responses at 20dB (click stim) on left.

• VRA with masking for audio

WVAS: hearing may deteriorate in both ears, need to maintain auditory function for future amplification
Child B: Management options

Parents considered the information and requested Left hearing aid fitting:

- HA is worn majority of waking hours,
- From 1 yr child takes out HA when battery dead
- Recently asked for HA after infection

BUT continues to startle to sudden onset sounds both with and without amplification
What objective outcome measures of HA benefit can we use?

- Localisation
- Aided Ling sounds from aided side
- Aided speech discrimination at 2 years

In quiet 55 dB: 3 conditions: Unaided = 82%
- Left Aided: Savia Art 311 = 82%
- Left Aided: Audeo smart + freq comp = 90%
How to optimise benefit from speech test results?

Case study 3: female 6 years old

Closed set test
Take best ear 3 freq average: 80 dB x 0.4 = 32 dB
Add to NH level for test = 30 dB
Present at 62 dB
Check real ear measure prescription, especially compression threshold (CT)
### Case study 3: Scores (no acclim, in one 2 hour appt)

<table>
<thead>
<tr>
<th></th>
<th>Open set wds</th>
<th>Trad HA</th>
<th>Freq Comp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>60 dB</td>
<td>50 dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>88%</td>
<td>76%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>97%</td>
<td>91%</td>
</tr>
<tr>
<td></td>
<td>Ling 5 /u i a/ /sh s/</td>
<td>45 dB</td>
<td>55 dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>45 dB</td>
<td></td>
</tr>
<tr>
<td>Closed set</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detect 62 dB</td>
<td></td>
<td>71%</td>
<td>100%</td>
</tr>
<tr>
<td>Discrim 62 dB</td>
<td></td>
<td>75%</td>
<td>97%</td>
</tr>
<tr>
<td>Vowel in noise</td>
<td></td>
<td>91%</td>
<td>100%</td>
</tr>
</tbody>
</table>
Case-study 3: phoneme analysis

Errors on closed set: Trad HA
Disc: kick/tick, bug/buzz, stork/chalk, fat/cat, white/right
Vowel: cat/cut, tar/tie, bark/buck
Det: bee/bees, shoe/sue, bean/bee

Errors on closed set: FC HA
None, except Disc: pick/thick

The confusions show benefit is NOT JUST FOR high frequency fricative detection but for discrimination of ALL speech sounds
Speech-based testing is crucial for:

- Validating functional benefit of Hearing aid fitting
- Fine-tuning amplification on an informed basis
- Information on expectations (and limitations) of hearing aid use and benefit
- Monitoring current progress and setting targets for habilitation

Thanks for listening