Early Acoustic Hearing and Spoken Language Skills of Children with Cochlear Implants

American Cochlear Implant Alliance

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There are no conflicts of interest to report
Hearing Device Possibilities –
*Depends on Severity of Hearing Loss*

- Normal Hearing
  *All acoustic hearing*
  - Bilateral Hearing Aids (HA)
  - Bimodal Devices
  - Bilateral Cochlear Implants (CI)
  - More Hearing Loss
    *All electric hearing*

- NH
- HA
- CI
- HA
- CI
- NH
Speech Perception

Two main areas of speech perception:

- **Segmental** Perception: “what is said”
  - vowels and consonants; words; sentences

- **Suprasegmental** Perception: “how something is said” or “who said it”
  - prosody, intonation, stress; talker characteristics (emotion, gender, age, accent, etc.)

Both types of perception are necessary for effective spoken communication and spoken language development (Abercrombie, 1967; Pisoni, 1997)
## CI Participants: Audiological Info

<table>
<thead>
<tr>
<th>CI Participants (n = 117)</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at Test (years)</td>
<td>7.0</td>
<td>1.3</td>
<td>4.8 – 9.4</td>
</tr>
<tr>
<td>Age at 1&lt;sup&gt;st&lt;/sup&gt; HA (months)</td>
<td>10</td>
<td>8.4</td>
<td>1 – 29</td>
</tr>
<tr>
<td>Age at 1&lt;sup&gt;st&lt;/sup&gt; CI (years)</td>
<td>2.1</td>
<td>1.1</td>
<td>0.67 (8 mos) – 4.6</td>
</tr>
<tr>
<td>Unaided PTA* (dB HL)</td>
<td>92</td>
<td>19</td>
<td>30 – 125</td>
</tr>
<tr>
<td>Age at 2&lt;sup&gt;nd&lt;/sup&gt; CI (yrs)</td>
<td>2.6</td>
<td>1.4</td>
<td>0.7 – 6.7</td>
</tr>
</tbody>
</table>

**Device Configuration**
- Bimodal (29), Sequential Bilateral (65), Simultaneous Bilateral (23)

**CI Manufacturer**
- Cochlear (90), Advanced Bionics (23), MED-EL (4)

*PTA: pure-tone average .5, 1, 2 kHz (dB HL)*
Composite Speech Perception Scores

Used Principal Components (PC) Analyses to create two composite speech perception scores:

1) **Segmental PC** (LNT-Q, LNT-N, OlimSPAC)

2) **Suprasegmental PC** (talker, stress, emotion & non-word stress pattern scores)
Results: Segmental Perception

N = 117 CI children
Results: Supra-segmental Perception

N = 117 CI children
Quantifying “Early Acoustic Hearing Experience”

<table>
<thead>
<tr>
<th>Device Group</th>
<th>Dur of Acoustic Exp (yrs)</th>
<th>Unaided PTA (dB HL) associated with</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simultaneous Bilateral CIs</td>
<td>Age at Cl surgery – Age at 1st HA</td>
<td>Pre-implant better-ear</td>
</tr>
<tr>
<td>Sequential Bilateral CIs</td>
<td>Age at 2nd Cl surgery – Age at 1st HA</td>
<td>Pre-implant 2nd CI ear</td>
</tr>
<tr>
<td>Bimodal (C1 &amp; HA)</td>
<td>Age at Test – Age at 1st HA</td>
<td>Current HA ear</td>
</tr>
<tr>
<td><strong>TOTALS [N = 117]</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>2.6 (2.3)</td>
<td>92 (19.0)</td>
</tr>
<tr>
<td>Range</td>
<td>0 – 9.1</td>
<td>30 - 125</td>
</tr>
</tbody>
</table>
Multi-stage Regression Models to predict Segmental & Suprasegmental Perception

Steps, variables entered:

1) **Demographic/child/device** characteristics (nonverbal IQ, age at test, maternal education, gender, age at 1\(^{st}\) CI)

2) **Hearing main** effects: Unaided PTA and Duration of Acoustic Experience

3) **Hearing non-linear & interaction** effects of Unaided PTA and Duration of Acoustic Experience
RESULTS of Models that predict Segmental Perception

<table>
<thead>
<tr>
<th>STEPS</th>
<th>Predictor Variables (Those in Bold are Significant)</th>
<th>% Variance Explained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic/child</td>
<td>Nonverbal IQ, Test Age, Maternal Education, Gender, Age 1st CI</td>
<td>36</td>
</tr>
<tr>
<td>Demographic/child, + Hearing</td>
<td>Nonverbal IQ, Test Age, Maternal Education, Gender, Age 1st CI, Unaided PTA, Duration of Acoustic Experience (DurAcExp)</td>
<td>39</td>
</tr>
<tr>
<td>Demographic/child, + Hearing, + Interactions</td>
<td>Nonverbal IQ, Test Age, Maternal Education, Gender, Age 1st CI, Unaided PTA, Duration of Acoustic Experience (DurAcExp), Unaided PTA x DurAcExp</td>
<td>42</td>
</tr>
</tbody>
</table>
Model Results:
Segmental PCA score = $f(\text{Unaided PTA, DurAcExp})$

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**UNAIDED PTA**

- **-1 SD:**
  - Unaided PTA of 73 dB HL

- **Mean:**
  - Unaided PTA of 92 dB HL

- **+1 SD:**
  - Unaided PTA of 111 dB HL
RESULTS of Models that predict Suprasegmental Perception

<table>
<thead>
<tr>
<th>STEPS</th>
<th>Predictor Variables (Those in Bold are Significant)</th>
<th>% Variance Explained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic/child</td>
<td>Nonverbal IQ, Test Age, Maternal Education Gender, Age 1(^{st}) CI</td>
<td>35</td>
</tr>
<tr>
<td>Demographic/child, + Hearing</td>
<td>Nonverbal IQ, Test Age, Maternal Education Gender, Age 1(^{st}) CI, <strong>Unaided PTA</strong>, Duration of Acoustic Experience (DurAcExp)</td>
<td>39</td>
</tr>
<tr>
<td>Demographic/child, + Hearing, + Interactions</td>
<td>Nonverbal IQ, Test Age, Maternal Education Gender, Age 1(^{st}) CI, <strong>Unaided PTA x DurAcExp(^{2})</strong></td>
<td>46</td>
</tr>
</tbody>
</table>
Model Results:

Suprasegmental PC score = $f(\text{Unaided PTA, DurAcExp}^2)$

UNAIDED PTA

-1 SD: Unaided PTA of 73 dB HL
Mean: Unaided PTA of 92 dB HL
+1 SD: Unaided PTA of 111 dB HL
Summary and Conclusions for these Pediatric CI Recipients

Duration of Acoustic Experience (i.e., with a HA) facilitates segmental and suprasegmental perception, but

- these effects are dependent on level of hearing (unaided PTA, 72, 92, 110 dB HL), and

- the magnitude and form of the effects differ for segmental and suprasegmental perception
  
  - Segmental: magnitude is smaller; interaction of Duration and PTA is linear
  
  - Suprasegmental: magnitude is greater; interaction of Duration and PTA is non-linear (plateaus \( \sim 3\text{-}4 \) years)
Both segmental and suprasegmental perception contribute significant independent variance to \textit{receptive vocabulary (PPVT)}.

Suprasegmental perception alone contributes significant independent variance to:

- comprehension of connected language (CELF receptive)
- reading achievement (Woodcock Reading Mastery Test).
Clinical Implications

- For children with severe losses, a period of HA use in conjunction with a CI may be the best option.

- For children with the most profound losses, early bilateral CIs may be the best option.