Development of spoken word-learning skills after cochlear implantation: Access to sound is just the beginning

Derek Houston, PhD

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Research Funding
- R01DC006235 (Houston)
- IU Collaborative Research Grant (Houston & Yu)
- T32 DC00012 (Pisoni)

Collaborators & Funding

Claire Monroy
Heidi S. Neuburger
Seth Foster
Steven Elmingher
Sami Gharbi
Luis Hernandez
Irina Castellanos Esther Chen Chen Yu David B. Pisoni Linda Smith

Cochlear Implantation in Children
Provides access to sound /dag/

Real-time mechanisms of word learning during social interaction in young deaf children with cochlear implants
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Cochlear Implantation in Children

- Permanent hearing loss prevalence rate: 1-3 in 1000 births
- Cochlear implants (CIs) stimulate the surviving spiral ganglion cells of the auditory nerve

Important Demographic Factors

- Age at CI
- Amount of residual hearing
- Duration of deafness
- Length of CI use
- Number of electrodes inserted
- Communication mode
- Amount of speech-language therapy
- Etiology of hearing loss

Cochlear Implantation in Children

- Provide individuals with profound hearing loss access to sound
- Large individual variability in language outcomes after implantation

(Pisoni et al., 2000)
### Important Demographic Factors
- Age at CI
- Amount of residual hearing
- Duration of deafness
- Length of CI use
- Number of electrodes inserted
- Communication mode
- Amount of speech-language therapy
- Etiology of hearing loss

### Question
- What underlying cognitive and linguistic skills does early auditory experience affect?

### CI < 1 Year vs. 1-2 Years

<table>
<thead>
<tr>
<th>Better Outcomes for CI&lt;1</th>
<th>No Differences</th>
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<tbody>
<tr>
<td>Dettman et al., 2007</td>
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**CI < 1 Year vs. 1-2 Years**

**Better Outcomes for CI < 1**
- Reynell receptive
- PLS receptive and expressive
- RITLS receptive and expressive
- Oral and written language skills
- Peabody Picture Vocabulary Test
- Performance IT-MAIS
- Auditory association
- Babbling
- DEAP
- Speech intelligibility rating

**No Differences**
- CNC
- LNT
- Mr. Potato Head Task
- Speech discrimination
- Reynell expressive

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**Word Learning Experiment**
(Houston et al., 2012, Dev Sci)
- Does early CI lead to better word learning?
- Early: 6.4–11.8 months
- “Late:” 12.2–15.6 months
- Profound hearing loss
- 1-1.5 years post-CI
- Compared to NH chronologically age-matched – “NHCA”
- Used a variant of the Intermodal Preferential Looking Paradigm

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**Demographic Variables for Early and Late CI**

<table>
<thead>
<tr>
<th></th>
<th>Early CI(10)</th>
<th>Late CI(10)</th>
<th>Sig diff?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at CI (mos)</td>
<td>9.6 (6.4-11.8)</td>
<td>14.3 (12.2-15.6)</td>
<td>Yes</td>
</tr>
<tr>
<td>Pre-CI aided PTA (dB)</td>
<td>87 (82-90)</td>
<td>88 (82-90)</td>
<td>No</td>
</tr>
<tr>
<td>Communication Mode</td>
<td>7 OC 3 TC</td>
<td>6 OC 4 TC</td>
<td>No</td>
</tr>
<tr>
<td># Bilateral at test</td>
<td>2</td>
<td>2</td>
<td>No</td>
</tr>
<tr>
<td>Hearing age at test (mos)</td>
<td>15.8 (10.4-20.8)</td>
<td>14.8 (10.5-20.3)</td>
<td>No</td>
</tr>
<tr>
<td>Maternal Education (yrs)</td>
<td>15.0 (12-20)</td>
<td>13.8 (12-18)</td>
<td>No</td>
</tr>
</tbody>
</table>

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**Intermodal Preferential Looking Paradigm (IPLP)**
### Partial Correlations (3-4 years post-CI)
(Controlling for age at CI and residual hearing)

<table>
<thead>
<tr>
<th></th>
<th>Vocab (PPVT)</th>
<th>Rec Lang (PLS-aud)</th>
<th>Exp Lang (PLS-exp)</th>
<th>Speech Perc (LNT-words)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Word Learning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearson’s r</td>
<td>.60*</td>
<td>.70****</td>
<td>.59*</td>
<td>.21</td>
</tr>
<tr>
<td>N</td>
<td>18</td>
<td>16</td>
<td>16</td>
<td>18</td>
</tr>
</tbody>
</table>

*p<.05; ***p<.01

### Conclusions
- No evidence so far that CI <1 year leads to better hearing or speech perception than CI 1–2 years
- CI <1 year leads to better novel word-learning skills
- Early word-learning skills are important for language outcomes

What leads to better word-learning skills?

### Interaction and Language
- Joint attention associated with vocabulary
  - Tomasello & Todd, 1983; Morales et al., 2000; Beuker et al., 2013; Cejas et al., 2014
- Following attention better than directing attention
  - Dunham et al, 1993; Tomasello & Farrar, 1986; Yu & Smith, 2012
- Parent responsivity positively associated with language
  - Bornstein et al., 1999; Tamis-LeMonda et al., 2001; Pressman et al, 1999; Quittner et al., 2013

### How does auditory experience affect word-learning skills?

![Diagram showing the relationship between Auditory Experience, Speech Perception, and Word Learning]

<table>
<thead>
<tr>
<th>Auditory Experience</th>
<th>Speech Perception</th>
<th>Word Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>

### How does auditory experience affect word-learning skills?

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Effects of Hearing Experience on Parent-Child Interactions

- NH-D/HH differences in joint attention, turn-taking, overlapping speech, parents’ referential cues
  - Fagan et al., 2014; Lund & Schuele, 2015; Morgan et al., 2014; Tasker et al., 2010

Limitations of current work on interactions with D/HH children

- Most focus on parent rather than bi-directional interaction
- Little work on micro-level, real-time properties specific to word learning

Three Studies/Analyses

1. Object-related utterances by parents and child attention to objects
   - Attention and object learning (e.g., Macroy-Higgins & Montemarano, 2016)

2. Synchrony of parent naming and child attention
   - Synchrony and word learning (e.g., Yu & Smith, 2012)

3. Joint attention
   - JA and vocabulary (e.g., Tomasello & Todd, 1983)

Dyad Play Session
In-Hand and Eye Tracking

Parents’ egocentric view

Infants’ egocentric view

35 mos old; 15 mos CI use

Set 1
Ballee  Dooga  Teeva

Set 2
Foma  Mobit  Kooka

Preferential Looking Paradigm (PLP)
Examples of Infant’s and Parent’s Gaze Data Stream

Participants

<table>
<thead>
<tr>
<th>Device</th>
<th>Chronological Age</th>
<th>Hearing Age</th>
<th>Hearing Status</th>
<th>Gender</th>
<th>Age</th>
<th>Age</th>
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</thead>
<tbody>
<tr>
<td>CI</td>
<td>37</td>
<td>12</td>
<td>LVA</td>
<td>M</td>
<td>36</td>
<td>13</td>
</tr>
<tr>
<td>HA</td>
<td>36</td>
<td>25</td>
<td>Unknown</td>
<td>F</td>
<td>36</td>
<td>24</td>
</tr>
<tr>
<td>CI</td>
<td>34</td>
<td>14</td>
<td>Unknown</td>
<td>F</td>
<td>35</td>
<td>14</td>
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<tr>
<td>CI</td>
<td>30</td>
<td>10</td>
<td>Unknown</td>
<td>F</td>
<td>28</td>
<td>12</td>
</tr>
<tr>
<td>HA</td>
<td>27</td>
<td>22</td>
<td>Unknown</td>
<td>M</td>
<td>25</td>
<td>23</td>
</tr>
<tr>
<td>M</td>
<td>32.8</td>
<td>16.6</td>
<td>Unknown</td>
<td>M</td>
<td>32</td>
<td>17.2</td>
</tr>
</tbody>
</table>

Three Studies/Analyses

1. Object-related utterances by parents and child attention to objects
2. Synchrony of parent naming and child attention
3. Joint attention
Utterances and Attention
(Chen, Castillanos, Yu, Houston, 2019, *Infancy*)

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
</table>
| Information | Providing information, such as label, features, or actions about the toy object | “That’s a wawa.”  
“Wawa is green.”  
“It goes round, round, round.” |
| Question | Asking a question about the toy object            | “Why do you like this one?”  
“Is that a hammer?” |
| Directive | Telling or directing child to do something        | “Spin it.”  
“Show me the wawa.” |
| Other   | Utterances that do not fit in the above-mentioned types | “I like this one.”  
“Oh, well, that one.” |

Utterances and Attention

(A) Parent-aid

(B) Child-aid

(C) Other

Target of OK or Gaze

- Blue object
- Green object
- Red object

Utterances and Attention

(A) HL

(B) CA

(C) HA
Three Studies/Analyses

1. Object-related utterances by parents and child attention to objects
   - Less effect on children with HL
2. Synchrony of parent naming and child attention
3. Joint attention

Naming Synchrony
(Chen, Castellanos, Yu, Houston, 2019, IBaD)
### Naming Synchrony

<table>
<thead>
<tr>
<th>Partial overlap</th>
<th>Complete overlap</th>
<th>Total Hits</th>
</tr>
</thead>
<tbody>
<tr>
<td>HL</td>
<td>0.11</td>
<td>0.16</td>
</tr>
<tr>
<td>CA</td>
<td>0.14</td>
<td>0.32</td>
</tr>
<tr>
<td>HA</td>
<td>0.13</td>
<td>0.27</td>
</tr>
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Table 2: Proportion of Parent’s Utterances Categorized as Hits and Misfires.

### Three Studies/Analyses

1. **Object-related utterances by parents and child attention to objects**
   - Less effect on children with HL
2. **Synchrony of parent naming and child attention**
   - Less synchrony
3. **Joint attention**

### Joint Attention

(Chen, Castillanos, Yu, Houston, in press, *DevSci*)

<table>
<thead>
<tr>
<th>Participant</th>
<th>Chronological Age</th>
<th>Hearing age</th>
<th>Sex</th>
<th>Degree of Hearing Loss</th>
<th>Hearing Device</th>
<th>Left</th>
<th>Right</th>
<th>Age</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24</td>
<td>15</td>
<td>F</td>
<td>profound</td>
<td>Cochlear implant</td>
<td>24</td>
<td>16</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>27</td>
<td>15</td>
<td>M</td>
<td>severe</td>
<td>Cochlear implant</td>
<td>25</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>28</td>
<td>13</td>
<td>F</td>
<td>profound</td>
<td>Cochlear implant</td>
<td>26</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>4</td>
<td>30</td>
<td>10</td>
<td>F</td>
<td>severe to profound</td>
<td>Cochlear implant</td>
<td>28</td>
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<tr>
<td>5</td>
<td>34</td>
<td>14</td>
<td>F</td>
<td>severe</td>
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<td>14</td>
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<td>14</td>
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Mean age: 30.9, 15.7, 30.0, 16.1
Joint Attention

Joint Attention - Results

- No group differences:
  - Number or mean duration of JA episodes
  - % child-led vs parent-led
  - Amount of face looking by parents or children

Parent-Led Joint Attention

Child-Led Joint Attention
Three Studies/Analyses

1. Object-related utterances by parents and child attention to objects
   - Less effect on children with HL
2. Synchrony of parent naming and child attention
   - Less synchrony
3. Joint attention
   - More use of face looks by children

Summary and Conclusions

- The coordination of parents labeling objects when children attend to those objects may be a challenge
- What can be done?
  - General awareness of coordination challenges
  - Things to keep in mind:
    - Talking about objects may be less effective for maintaining children’s attention to objects
    - Children may shift attention away from the object the parent is holding to look at the parent’s fact.
- But findings are preliminary!

Next Steps

- Auditory Experience
- Speech Perception
- WL-Relevant Interactions
- Word Learning

Future Directions

- Parent-child interactions → Word learning
- Malleability of parent-child interactions
- Does parent-child interaction training lead to better word learning?