Cognitive and Demographic Predictors of Cochlear Implant Outcomes in Adults with Cochlear Implants

American Cochlear Implant Alliance
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Disclosures

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• Pilot funding from Cochlear, Inc., for aural rehab study
Mission Statement

(1) To examine the auditory, linguistic, and cognitive factors that contribute to variability in speech recognition outcomes for adults with cochlear implants. Understanding these sources of variability should help us to predict outcomes preoperatively and to explain why some individuals do not perform well with an implant.

(2) To develop novel rehabilitation interventions for adults with cochlear implants, targeting auditory, linguistic, and cognitive skills. We predict that individualized rehabilitation plans that are tailored to individual patients' needs will optimize speech recognition outcomes.
Simulations

8-channel vocoded

Original

8-channel vocoded

Original
Outcome Variability – Speech Recognition

• Large and frustrating (0 to 100% scores)

• Likely relates to abilities within four areas:

**AS**: Auditory Sensitivity
**PO**: Perceptual Organization
**LS**: Language Skills
**CF**: Cognitive Factors

AS  PO  LS  CF

Speech Understanding
Demographic factors and speech recognition

• Residual hearing pre-op (Lazard et al., 2012; Roberts et al., 2013)
• Longer duration of deafness (Green et al., 2007)
• Age (Williamson et al., 2009; Chatelin et al., 2004)
Increasingly clear that neurocognitive functions contribute to the ability to recognize degraded speech

- Working memory capacity (Arehart et al., 2013)
- Information-processing speed (Salthouse, 1996; Carroll et al., 2016)
- Inhibitory control (Sörqvist & Rönnberg, 2012; Moberly et al., 2016)
- Nonverbal reasoning (Holden et al., 2013)
- Perceptual closure (George et al., 2007)
Participants

CI candidates (ages 49 to 94 years)
- 31 adult, postlingually deaf CI candidates
  - Pre-operative demographic and neurocognitive measures
  - Pre-operative best-aided speech recognition
- 9 with post-operative speech recognition testing at ≥ 6 months post-activation
Methods

“Neurocognitive” tasks (non-auditory)

- Working memory
  - Digit Span, Object Span, Symbol Span
- Inhibitory control
  - Computerized Stroop
- Speed of lexical access (and phonological)
  - TOWRE words (and nonwords)
- Nonverbal reasoning
  - Raven’s Progressive Matrices
- Perceptual closure
  - Fragmented sentences
- Verbal learning and memory
  - CVLT
Methods

- Cognitive tasks (all non-auditory)
  - Working memory - Digit Span (Object Span, Symbol Span)

![Image of numbers sequence]
Methods

- Cognitive tasks (all non-auditory)
  - Inhibitory control - Computerized Stroop

\[
\begin{array}{cccc}
d = \text{red} & f = \text{green} & j = \text{blue} & k = \text{black} \\
\end{array}
\]
Methods

Cognitive tasks (all non-auditory)
- Rapid reading - TOWRE words and non-words

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Methods

- Cognitive tasks (all non-auditory)
  - Fluid Intelligence – Raven’s Progressive Matrices
Methods

Cognitive tasks (all non-auditory)

- Perceptual closure - Fragmented Sentences

MY NEPHEW IS HAVING A PARTY

MY BROTHER COLLECTS STAMPS AND COINS
Methods

• Cognitive tasks (all non-auditory)
  – Verbal learning and memory - CVLT

• Multi-trial free recall measure

• Detailed, quantitative information regarding:
  – Learning rates
  – Proactive interference (PI)
  – Retroactive interference (RI)
  – Retrieval inhibition
  – Release from PI
  – Organizational strategies: Semantic, serial, subjective clustering of output responses
Methods

• PRE-op speech recognition, best-aided
  – AzBio Sentences in quiet
  – AzBio Sentences in babble (+10 dB SNR)
  – CUNY Sentences
    • Auditory-only
    • Combined AV
    • Visual-only
Methods

• POST-op speech recognition, best-aided
  – Harvard Standard Sentences
    • “The boy was there when the sun rose.”
  – Harvard Anomalous Sentences
    • “The deep buckle walked the old crowd.”
  – PRESTO Sentences
    • “He ate four extra eggs for breakfast.”
  – CID Words
    • “Say the word ‘book’.”
Results

Bivariate correlations between PRE-operative speech recognition and demographic factors for 31 CI candidates

<table>
<thead>
<tr>
<th>Pre-Op Speech Recognition</th>
<th>Age (Years)</th>
<th>SES</th>
<th>Best PTA</th>
<th>Duration Deafness (Years)</th>
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</thead>
<tbody>
<tr>
<td>AzBio Sentences in Quiet (% words correct)</td>
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<td>AzBio Sentences in Babble (+10 SNR)</td>
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<td>CUNY Sentences in Quiet - A-only (% words correct)</td>
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<td>CUNY Sentences in Quiet - AV (% words correct)</td>
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<td>-.46</td>
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<tr>
<td>CUNY Sentences in Quiet - V-only (% words correct)</td>
<td>-.68</td>
<td>.41</td>
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X = p < .10
XX = p < .05
XXX = p < .01
Results

Bivariate correlations between PRE-operative speech recognition and cognitive factors for 31 CI candidates

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<td>CUNY Sentences in Quiet - V-only (% words correct)</td>
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<th>Stroop incong</th>
<th>Digit Span (points)</th>
<th>Frag Sent (% words)</th>
<th>TOWRE non-words</th>
<th>Vocab (WordFam)</th>
<th>Raven’s (# correct)</th>
<th>CVLT (LAT1)</th>
<th>CVLT (LAT5)</th>
<th>CVLT (SDLA)</th>
<th>CVLT (SDCR)</th>
<th>CVLT (Rec)</th>
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<td>CUNY Sentences in Quiet - A-only (% words correct)</td>
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<tr>
<td>CUNY Sentences in Quiet - AV (% words correct)</td>
<td>.38</td>
<td>.78</td>
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<tr>
<td>CUNY Sentences in Quiet - V-only (% words correct)</td>
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</tbody>
</table>

No correlations with word reading (WRAT), Stroop
### Results

Participant demographics for 9 individual cochlear implant candidates with 6-month post-activation testing

<table>
<thead>
<tr>
<th>Participant</th>
<th>Gender</th>
<th>Age (years)</th>
<th>SES</th>
<th>Implant</th>
<th>Etiology of Hearing Loss</th>
<th>Better ear PTA (dB HL)</th>
<th>Harvard Standard Sentences (% words correct)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300001</td>
<td>F</td>
<td>76</td>
<td>12</td>
<td>AB</td>
<td>Meniere's</td>
<td>101.25</td>
<td>0.0</td>
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<tr>
<td>300002</td>
<td>M</td>
<td>82</td>
<td>-</td>
<td>Cochlear</td>
<td>Noise</td>
<td>78.75</td>
<td>42.0</td>
</tr>
<tr>
<td>300005</td>
<td>M</td>
<td>60</td>
<td>18</td>
<td>Cochlear</td>
<td>Trauma</td>
<td>112.5</td>
<td>43.2</td>
</tr>
<tr>
<td>300012</td>
<td>M</td>
<td>67</td>
<td>7.5</td>
<td>Cochlear</td>
<td>Noise</td>
<td>77.5</td>
<td>25.0</td>
</tr>
<tr>
<td>300017</td>
<td>M</td>
<td>78</td>
<td>6</td>
<td>Cochlear</td>
<td>Progressive, noise</td>
<td>87.5</td>
<td>12.3</td>
</tr>
<tr>
<td>300019</td>
<td>M</td>
<td>65</td>
<td>42</td>
<td>Cochlear</td>
<td>Genetic, noise</td>
<td>91.25</td>
<td>71.6</td>
</tr>
<tr>
<td>300020</td>
<td>M</td>
<td>74</td>
<td>36</td>
<td>Cochlear</td>
<td>Genetic, progressive, noise</td>
<td>53.76</td>
<td>85.6</td>
</tr>
<tr>
<td>300022</td>
<td>F</td>
<td>61</td>
<td>-</td>
<td>Cochlear</td>
<td>Noise</td>
<td>73.75</td>
<td>40.7</td>
</tr>
<tr>
<td>300025</td>
<td>M</td>
<td>68</td>
<td>42</td>
<td>Cochlear</td>
<td>Progressive, noise</td>
<td>71</td>
<td>69.9</td>
</tr>
</tbody>
</table>

Notes: SES: socioeconomic status; PTA: pure-tone average; HL: hearing level
## Results

Bivariate correlations between POST-operative speech recognition and demographic factors for 9 CI candidates

<table>
<thead>
<tr>
<th>POST-Op Speech Recognition</th>
<th>Age (Years)</th>
<th>SES</th>
<th>Best PTA</th>
<th>Duration Deafness (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvard Standard Sentences (% words correct)</td>
<td>0.91</td>
<td></td>
<td></td>
<td>-0.82</td>
</tr>
<tr>
<td>Harvard Standard Sentences (% sentences correct)</td>
<td>0.86</td>
<td>-0.64</td>
<td>-0.81</td>
<td></td>
</tr>
<tr>
<td>Harvard Anomalous Sentences (% words correct)</td>
<td>0.85</td>
<td>-0.65</td>
<td>-0.78</td>
<td></td>
</tr>
<tr>
<td>Harvard Anomalous Sentences (% sentences correct)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>PRESTO Sentences (% words correct)</td>
<td>0.90</td>
<td>-0.67</td>
<td>-0.84</td>
<td></td>
</tr>
<tr>
<td>PRESTO Sentences (% sentences correct)</td>
<td>0.87</td>
<td>-0.67</td>
<td>-0.74</td>
<td></td>
</tr>
<tr>
<td>CID Words (% words correct)</td>
<td>0.84</td>
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<td>-0.65</td>
</tr>
</tbody>
</table>

X = p < .10
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## Results

Bivariate correlations between POST-operative speech recognition and cognitive factors for 9 CI candidates

<table>
<thead>
<tr>
<th>POST-Op Speech Recognition</th>
<th>Digit span (points)</th>
<th>Digit span (response time)</th>
<th>Object span (points)</th>
<th>Object span (response time)</th>
<th>TOWRE words</th>
<th>CUNY V-only</th>
<th>CVLT LAT5</th>
<th>CVLT LB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvard Standard Sentences (% words correct)</td>
<td>.59</td>
<td></td>
<td></td>
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<td></td>
<td>.62</td>
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<td>.73</td>
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<td>Harvard Standard Sentences (% sentences correct)</td>
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<tr>
<td>Harvard Anomalous Sentences (% words correct)</td>
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<td>.76</td>
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<tr>
<td>Harvard Anomalous Sentences (% sentences correct)</td>
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<td>-.70</td>
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<tr>
<td>PRESTO Sentences (% words correct)</td>
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<td>.92</td>
<td>.59</td>
<td>.63</td>
<td></td>
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<tr>
<td>PRESTO Sentences (% sentences correct)</td>
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<td>CID Words (% words correct)</td>
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</tbody>
</table>

X = p < .10
XX = p < .05
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No correlations with word reading (WRAT), MMSE, Stroop response times, Symbol span, Fragmented sentences, rapid reading TOWRE non-words, Vocabulary (WordFam), Raven's
Clinical implications

• Demographic and neurocognitive factors contribute to the ability to understand degraded speech, both before and after cochlear implantation.

• A pre-operative demographic and neurocognitive battery shows promise in helping us prognosticate speech recognition outcomes for patients considering cochlear implantation.

• Future work aims to identify strengths and deficits pre-operatively to encourage early aural rehabilitation efforts to optimize CI outcomes.
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