Individual Variability and the Effects of Aging in Cochlear-Implant Users

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The “one-third” rule (Abi Kulkarni, Advanced Bionics)
For any given experimental manipulation in a study with CI users:
• 1/3 will show a performance increase 😊
• 1/3 will show no change in performance 😞
• 1/3 will show a performance decrease 😞

Hence, your p-values will be large.

Purpose of a cochlear implant (CI) is to restore speech understanding

How a CI works
1. Sound picked up by microphone
2. Speech processor analyzes (vocoded) sound
3. Code sent to coil and transmitted through skin
4. Implant interprets code and sends electrical pulses to the electrodes in the cochlea
5. Electrical pulses cause spiral ganglion/auditory nerve to fire

Some changes that occur with a CI
• Changes:
  – Finite number of electrodes (12-24)
  – Current spread (~1/8 cochlear length)
  – Envelope info transmitted via electrical pulses
  – Transfer only speech frequencies (e.g., 200-5000 Hz)
  – Shallow insertion depth
• Causes:
  – Poor frequency selectivity (~6-8 channels)
  – Reduced saliency of voice pitch and prosodic cues
  – Frequency-to-place mismatch

How is speech perceived with cochlear implants (CIs)?

How many older people are getting CIs?

• Improved surgical techniques
  o Duration of surgery
  o Less trauma
• Improved anesthesiology
• Improved arrays and speech coding strategies


Original visual demo conceived by Bob Shannon.
Percentage of older people (>65 yrs) using CIs has doubled in last decade

<table>
<thead>
<tr>
<th>Age Group</th>
<th>1996 Study</th>
<th>2013 Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>60-69 yrs</td>
<td>0-30%</td>
<td>0-60%</td>
</tr>
<tr>
<td>70-79 yrs</td>
<td>0-10%</td>
<td>0-60%</td>
</tr>
<tr>
<td>80-89 yrs</td>
<td>0-7%</td>
<td>0-30%</td>
</tr>
<tr>
<td>&gt;90 yrs</td>
<td>0%</td>
<td>0-30%</td>
</tr>
</tbody>
</table>

Assuming:
1. All companies have similar age distribution
2. 350,000 CI users worldwide
   - 70,000 CI users >65 yrs
   - 17,500 CI users >80 yrs

How do older CI users compare to younger?

- Blamey et al. (2013) retrospective multi-center study
- 15 international centers
- 2251 CI patients
  - Adults (>17 yrs)
  - Late onset of profound hearing loss (>15 yrs)
  - Recent date of implantation (>2002)

- Speech understanding scores converted to percentile ranks (removing any differences across centers)


Speech understanding is worse if age of implantation is later

Clark et al. (2012) Literature Review of CIs and Aging

- 31 peer-reviewed papers
- >50 yrs (N=8 papers) and >65 yrs (N=23 papers)

- Focused on clinical speech perception scores
- Some included quality-of-life measures

- In general, research shows that CIs are safe, improve speech understanding, and improve quality of life in older adults


CIs, audition, and aging research

What is missing? And why?

- No within-subjects experimental designs
- No cognitive measures
- No highly-controlled experiments using non-speech stimuli and research processors

(Actually, we CI research does many of these, albeit poorly)

High variability in CI performance weakens potential to perform impactful research of aging and audition

What are the sources of variability?


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Stage 4???

What are the sources of variability?

Etiology (physiological processes)
Duration of deafness (neural degeneration, uneven?)
Length of CI use (adaptation)
Surgical (trauma, insertion depth)
Clinical (device setting)
Temperament (practice, aural rehab, research studies)
Cognitive factors

How can we advance knowledge of effects of aging in CI users?

• Direct stimulation ~ headphone experiment
• Use simpler stimuli
  – Single electrodes
  – Constant-amplitude pulse trains

Gap detection thresholds in CI users comparable to NH listeners

Similar temporal rate limitation for CI and NH listeners for interaural time difference (ITD) sensitivity

Why use a channel vocoder?

• Create an intermediate step between NH and CI participants (similar to using YNH, ONH, YHI, OHI?)
• Understand cochlear-implant (CI) data (i.e., control for variability from subject-specific factors)
• Ask questions that cannot be asked in real CI users
  – Time (longer studies) with parametric investigations
  – Population (not many with bilateral or single-sided deafness)
  – Imaging and electrophysiology easier
Older adults need more channels (~3) to understand noise vocoded words.

![Graph showing proportion correct vs. number of random trials for younger vs. older adults.]


Older listeners worse at processing noise vocoded phonemes.

![Graph showing identification accuracy for younger vs. older listeners.]


Envelope F0 discrimination worse for older listeners using noise vocoder.

![Graph showing distribution of F0 discrimination scores for younger vs. older listeners.]


Now we know what we are looking for...

- Older listeners have temporal and spectral deficiencies in processing degraded speech.

Should we be studying CIs, audition, and aging?

**Cons**

- Many sources of variability reduce effect sizes

**Techniques**

- Direct stimulation (simple & controlled stimuli)
- Vocoder (NH, CI simulated, CI || YNH, YHI, OHI)

**Pros**

- Growing number of older CI users (~70K)
- Plenty of room for new research (~33 clinical speech, ~7 vocoder, ~0 direct stimulation papers, 0 abstracts at CIAP2013, 2 abstracts at ASC2013)
- Perfect model to study central temporal processing?

Perfect model to study central temporal processing?

![Circle diagram showing overlap of peripheral, central, and cognitive processes.]

Peripheral

Central

Cognitive