Evaluation of Novel Physiologic Measures to Estimate Cochlear Implant Stimulation Levels

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Setting Stimulation Levels

Upper Stimulation Levels

Electrical Threshold – T levels
CI Patient Outcomes are Influenced by Stimulation Levels

- Geers et al. (2003), *Ear Hear*, 24(S1): 24S-35S.
No DSL for Cochlear Implants!
Setting Stimulation Levels for Children
Back to the Drawing Board

• Current clinical measures are imperfect:

• **Electrically-evoked compound action potential (eCAP)**
  – Poor to modest correlation with behavioral stimulation levels

• **Electrically-evoked stapedial reflex threshold (eSRT)**
  – Frequently absent with probe in implanted ear
  – Absent with conductive component
Evaluation of Novel Measures for Estimating CI Stimulation Levels

• 15 cochlear implant recipients (21 to 75 years old)

• Cortical Auditory Evoked Response – Single-sweep analysis/habituation
  – Estimate upper stimulation levels
  – Brain Products EEG system (64 channels) with stimuli presented via Custom Sound EP

• Functional Near Infrared Spectroscopy (fNIRS)
  – Estimate electrical threshold
  – NIRx fNIRS instrument with stimuli presented via Custom Sound EP
Pilot Study of EEG Imaging in Cochlear Implant Patients

Jace Wolfe, Sara Neumann, Junwei Ma, Fan Zhang, Yafen Chen, Han Yuan, Lei Ding
Lack of Habituation to Loud Sounds
Single-sweep CAER Response Habituation

- Psychophysical loudness scaling to define:
  - Comfortable but soft
  - Most comfortable
  - Loud but comfortable
  - Upper loudness limit

- Measure CAER amplitude across single sweeps at:
  - Comfortable but soft
  - Most comfortable
  - Loud but comfortable
  - Upper loudness limit
Representative subject #1, Implant on the left
Habituation Index using the Traditional N1 Amplitude
Representative subject #1, Implant on the left

Most significant habituation
No habituation
Preliminary Conclusions

CAER Habituation

- ERP N1 component is evident in all CI users and all sessions with different stimulus levels.
- Scalp topography of N1 is consistent with literature from healthy persons.
- However, the width of N1 component in CI users seems in general larger than those reported in healthy persons; some even show multiple peaks; the onset of N1 seems slightly earlier in CI users than healthy persons as well.
- The habituation effect is evident in trial-based ERP plots (as shown in previous slides).
- Sessions with loud sound stimuli (in particular loud upper limit sound level) indicate less habituation phenomena.
Setting Stimulation Levels

Electrical Upper Stimulation Level

Electrical Threshold
Functional Near Infrared Spectroscopy (fNIRS)
fNIRS for Measurement of Auditory Response
fNIRS

T Level Estimation

• Psychophysical loudness scaling to define:
  – T level = Very soft
  – 25% of electrical dynamic range
  – 50% of electrical dynamic range
  – Loud but comfortable

• Measure fNIRS response:
  – T level = Very soft
  – 25% of electrical dynamic range
  – 50% of electrical dynamic range
  – Loud but comfortable
Location of fNIRS Optodes
Representative subject #1, Implant on the left

HbO Time Course of at C Condition

HbO Peak Activation at C condition, (averaged between 10 s and 25 s)

Channel of Interest

Shaded grey area indicate that stimuli lasted from 0 s to 22 s.
Representative subject #1, Implant on the left:

<table>
<thead>
<tr>
<th>Relative Concentration Change (uM)</th>
<th>Time (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.20</td>
<td>0</td>
</tr>
<tr>
<td>-0.10</td>
<td>5</td>
</tr>
<tr>
<td>0.00</td>
<td>10</td>
</tr>
<tr>
<td>0.10</td>
<td>15</td>
</tr>
<tr>
<td>0.20</td>
<td>20</td>
</tr>
<tr>
<td>0.30</td>
<td>25</td>
</tr>
</tbody>
</table>

Shaded grey area indicates that stimuli lasted from 0 s to 22 s.

HbO Time Course of at T Condition
Shaded grey area indicate that stimuli lasted from 0 s to 22 s.
Representative subject #1, Implant on the left

Accumulated activations at all four conditions (from 5 s to 35 s)
Preliminary Conclusions

fNIRS at T Level

- 7 out of 7 subjects show significant change in HbO concentration at loud but comfortable stimulation
- 5 out of 7 show significant change in HbO concentration at T level (very soft)
- At T level, change in HbO appears soon after onset of stimulation
- Early activation of HbO at T level stimulation is significant in early pilot group (p<.05)
Thank you for your attention!!!

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