Can the Binaural Interaction Component of the Cortical Auditory Evoked Potential be Used to Optimize Interaural Electrode Matching for Bilateral Cochlear Implant Users?

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Binaural/Bilateral Stimulation

- Studies have shown that matching the cochlear position of stimulation across the two ears can be beneficial.
  - For normal hearing listeners, binaural sensitivity is improved when place of stimulation in the two ears is matched.
    - Henning, 1974; Nuetzel and Hafter, 1981
  - Mismatches between the frequency-to-electrode MAPs in the ears of a bilateral CI user can have a negative effect on speech reception.
    - Faulkner et al., 2005; Siciliano et al., 2006; Li and Fu, 2012; Goupell et al. 2013.
Electrophysiologic Measures of Binaural Processing

- **The Binaural Interaction Component (BIC) of the Cortical Auditory Evoked Potential (CAEP)**
  - Record the CAEP in Left monaural, Right monaural and Binaural stimulation conditions.
  - $BIC = (\text{Left monaural} + \text{Right monaural}) - \text{Binaural response}$

- **Theory**
  - **No Interaction:**
    - Binaural response = sum of left and right monaural responses
    - No BIC
  - **Significant Interaction**
    - Binaural response $\neq$ sum of left and right monaural responses
    - BIC will be present
    - Amplitude of the BIC may reflect extent of interaction
The BIC of the CAEP: Adult Subjects

- Normal-hearing adults
- Adult bilateral CI users
Research Question

Can the BIC of the eCAEP be Used to Optimize Interaural Electrode Matching for Bilateral CI Users?
Methods: Subjects

• Bilateral CI subjects
  » Seven bilateral CI users (39 to 53 yrs) were initially recruited, one subject was excluded due to the inability of performing the ITD sensitivity measures.
  • Bilateral MED-El devices
  » > 2 years of experience with both devices
  » There were no performance-based inclusion criteria.
Methods: Electrode Pairs and Stimulus

- **Electrode Pairs**
  - Right ear electrode: electrode 6 (R6)
  - Left ear electrodes: electrodes 3, 4, 5, 6, 7, 8, and 9

- **Stimulus**
  - L3 and L9 were not tested in S6 due to time constraint.

- **Stimulus**
  - Biphasic pulse train delivered directly to individual electrode via Research Interface Box 2.
  - Pulse rate: 600 pps
Methods: Psychophysical Measures

• **Loudness Estimation**
  » An ascending method of adjustment procedure.
  » Threshold (T) and the maximum comfortable (C) levels were measured for each subject and stimulating electrode.
  » The procedure were repeated three times for R6 and measured once for each stimulating electrode in the left ear.
  » The geometric average of the three trials was computed and these values were used to define the DR of the R6.
Methods: Psychophysical Measures

• Loudness Balancing
  » Two-interval, two-alternative forced-choice (2I, 2AFC) Two-down one-up procedure.
  » Stimulation level of R6 was fixed at 60% point of DR.
  » The level of the stimulus in the left ear was varied using an adaptive staircase procedure.
  » Subjects were asked to decide in which ear the sound was louder.
  » The test ended after a total of twelve reversals. The geometric average of the stimulus levels over the last six reversals was defined as the balanced loudness level.
Methods: Psychophysical Measures

• Sensitivity of Interaural Time Difference
  » The ITD was created by delay the onset of stimulus presented in one ear.
    • An exponential decay function was used to minimize effect of stimulation duration on ITD measures.
  » 3I, 2AFC, 3-down,1-up procedure.
    • The step size of ITD was varied using an adaptive procedure.
  » Subject was asked to decide which interval contained a different sound.
  » The test ended after a total of 16 reversals The geometric average of ITDs over the last six reversals was defined as the ITD threshold.
Methods: EEG Recordings

• General Parameters
  » Active electrodes: Fz, FCz, Cz; reference electrode: C7; ground electrode: Fpz
  » 0.1-100 Hz
  » Recording window: -100 to 800 ms
  » The horizontal and vertical electro-oculogram were monitored.
  » Artifact rejection threshold was set at 100 µV.
  » 3 replications of 100 sweeps were recorded for each stimulation condition.
Data Analysis

- BIC = (left monaural + right monaural)-binaural response.

- Peak-to-peak amplitude was measured between the negative peak occurring around 80-100 ms after the stimulus onset and the following positive peak.

- Normalized peak-to-peak amplitudes of the BIC and normalized ITD thresholds were plotted as a function of left ear electrodes.
Results: Exemplary Data

BICs recorded in S1

ITD and BIC amplitude functions
Results: Group Data

- **S1**: Normalized BIC amplitude vs. L3-L9 for Left ear electrode.
- **S2**: Normalized ITD threshold vs. L3-L9 for Left ear electrode.
- **S3**: Normalized BIC amplitude vs. L3-L9 for Left ear electrode.
- **S4**: Normalized BIC amplitude vs. L3-L9 for Left ear electrode.
- **S5**: Normalized ITD threshold vs. L3-L9 for Left ear electrode.
- **S6**: Normalized ITD threshold vs. L3-L9 for Left ear electrode.
Conclusions

• Substantial inter-subject variations in BIC amplitudes and ITD sensitivity were observed.

• Both BIC amplitudes and ITD sensitivity were affected by interaural electrode spacing.

• The potential clinical application of using the BIC of the eCAEP to match electrode pairs in bilateral CI users is still promising. However, further studies are warranted.
Thank you!
Questions