Introduction

Binaural hearing provides a listener with cues that aid in sound localization, namely inter-aural level and time differences (ITDs and ILDs). In addition, ITDs in the envelopes of modulated high frequency carriers may also aid localization.

Although patients with cochlear implant bi-lesion (BiCIs) are known to have improved sound localization abilities compared to single CI users, children with BiCIs still perform notably poorer than their normal hearing (NH) peers (Giraco-Calab and Litovsky, 2010).

One reason for this gap in performance is that CI speech processing algorithms discard the detailed temporal structure of the original signal, making it difficult to gain access to ITD information. A second reason is that pre-linguistically deafened children also lack early access to acoustic binaural input during particularly important developmental years, therefore their auditory system may be insensitive to binaural cues.

The aim of this study was to investigate the sensitivity of children who use BICIs to ITDs and ILDs and to compare their sensitivities to NH children participating in a CI simulation.

Methods

Participants

Ten children with bilateral cochlear Nucleus devices (Nucleus 24, Freedom, NS) participated in three experiments.

Ten NH children (ages 8-10 yrs) participated in similar tasks while listening to CI simulations using vocoders.

Materials

BiCIs were assessed using the Clinical Evaluation of Cochlear Implant Function (CECIF). CIAG and CIDJ were used.

Stimulus

A 300 ms, constant amplitude, 100 pulses per sec (pps) pulse train with a 250 µs pulse width was presented at a self-reported comfortable loudness level.

Stimuli were presented via a bi-laterally synchronized pair of Nucleus Implant Communicators (NICs).

NH children listened to a Gaussian Enveloped Pulse Train (4kHz center frequency, 100pps) via Ety McRae ETR-2 headphones.

Procedure

Subjects’ threshold, comfortable, and most comfortable levels were measured using the NICs.

A pitch matched pair was found via pitch magnitude estimation and direct pitch comparison.

NH subjects and subjects with BiCIs both completed lateralization and discrimination tasks. Children with BiCIs completed the tasks using the pitch matched pair.

Table 1: BCI Information

Table 2: Electrode pairs tested for each subject (Left/Right)

Experiment 1: Pitch Matched Pairs

**Methods**

- **Pitch Magnitude Estimation**: subjects were asked to rank pitch of interaural electrodes along a scale of 1-100.
- **Direct Pitch Comparison**: subjects were asked to compare pitch of interaural electrodes for 0, Δ, 2Δ, and 4Δ. Subjects had to report whether the sound was the same, higher, much higher, lower, or much lower in pitch than the first sound.

**Results**

- **Pitch Magnitude Estimation**
  - electrode was chosen based on the best pitch matched pairs in order to attempt to control for interaural mismatch.
  - percent of subject responded as “same”

Experiment 2: Lateralization

**Methods**

- **ILDs**: 0, ±50, 100, 200, 400, 800, 1600 μs
- **ILDs**: 1, 2, 5, 10, 20 current units (CU)

**Results**

- **ILDs**: percent of subject responded as “same”

Experiment 3: Discrimination

**Methods**

- **ILDs**: JND measurement was attempted with all children who use BiCIs but CIAG and CIDJ were the only subjects with measurable JNDS. CIAG and CIDJ had higher JNDS than their NH peers.

Conclusions

- **ILDs**: Some children with BiCIs are able to distinguish lateral positions when given ILDs similar to that observed for NH children. However, children with BiCIs are unable to perceive a systematic change in the lateral location of an auditory image as a function of ITD.

Acknowledgments

We would like to thank the families who participated in the study. We were supported by NIDCD (Grant No. R01DC012465) and ENT Institute (Grant No. K12RR024652). The authors declare no conflict of interest.

References

