Emergence of Spatial Hearing in Pediatric Bilateral Cochlear Implant Users

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In Children: Growing trend: Implant in both ears (bilateral)

In normal-hearing children:
Coordination of inputs from two ears in the auditory brainstem

In children fitted with Bilateral CIs:
No Coordination of inputs from the two ears
Complex acoustic waveforms can be decomposed into a slowly varying “envelope” (ENV) modulating a rapidly-varying “temporal fine-structure” (TFS).
Growing trend: Implant in both ears (bilateral)

Goal: provide CI users the ability to localize and to understand speech in noise at better SNR.
Results to date

Normal Hearing > Bilateral CIs > Unilateral CI

Children with Bilateral CIs perform better with than children with a single CI.

However, they are significantly worse than normal-hearing peers:

- Sound localization
- Speech in noise (e.g., Spatial release from masking)
What are the next steps?

Normal Hearing > Bilateral CIs > Unilateral CI

- Understand the sources of limitation on performance
- Design processors that overcome the limitations
- Study performance in children in order to know which binaural cues should be preserved and presented to the children
- Focus on multi-electrode stimulation, in order to ensure fidelity of speech signal
Spatial Release from Masking

- Improvement of speech intelligibility when the target is spatially separated or *perceived* to be spatially separated from the interferer(s)
- Reduction in masking through spatial separation

Co-located vs. Asymmetrically separated
Spatial Release from Masking (SRM)

Example:

SRT = 55 dB SPL  
SRT = 45 dB SPL

Co-located
SRM = 10 dB

Asymmetrically separated
Spatial Release from Masking

Misurelli & Litovsky (under review); Hess & Litovsky (in prep)
SRM in toddlers is related to # months of hearing experience with Bilateral CIs

Hess & Litovsky (in prep)
Some factors that limit performance

- Limited #channels & spectral degradation
- Neural pathway degradation
- Difference in the insertion depth of electrodes between ears
- Difference in spread of excitation in R & L ears
- Signal processing compromises acoustic cues
Binaural system is ideally suited for frequency-matched inputs from the right & left ears.
Approaches to restoring binaural inputs:
Bypass the microphones / processors.

Pitch-matched
Loudness balanced
1 pair of electrodes

Direct stimulation
- Small number of electrodes
- Precise control over stimulus reaching each electrode
- Excellent binaural cues
In NH Children: Simulate CI processing
Gaussian-enveloped tone (GET) pulse train (4 kHz center frequency, 100 pulses per second).

Task:
2- alternative forced choice (with feedback):
   Right-Left vs. Left-Right
Adaptive tracking algorithm
   1) vary ILD in dB (NH) or Current units (CI)
   2) vary ITD in μs

Ehlers et al. (in prep)
Just-noticeable difference (JND) threshold in children with BiCIs and NH Interaural Time Difference (ITD)
Just-noticeable difference (JND) threshold in children with BiCIs and NH

Interaural Level Difference (ILD)

Just-noticeable difference (JND) threshold in children with BiCIs and NH.

Interaural Level Difference

Threshold (dB)

Subjects

Threshold (CUs)
Binaural cue sensitivity using research processors: Research to date shows that:

→ ITDs highly “vulnerable” to deprivation.
→ ILDs are highly “recoverable” after long-term deafness
→ In adults and children