Visual and Somatosensory Cross-Modal Reorganization in Cochlear-Implanted Children and its Relationship to Speech Perception

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Background

- **Cross-modal reorganization (CMR)** occurs when a deprived sensory modality's cortical resources are recruited by other intact modalities
- Cross-modal reorganization has been proposed as a **source of variability** underlying **speech perception in hearing-impaired cochlear implant (CI) users** [1,2]
- Visual and somatosensory cross-modal reorganization of auditory cortex has been documented separately in children with CIs [3,4], but **reorganization in these modalities has not been documented within the same subject group**

Aim of the Study

- To examine cross-modal reorganization across both **visual and somatosensory modalities** within a single group of CI children (n=10) using high-density electroencephalography

Methods

- Analyzed **evoked potentials** in response to visual and somatosensory stimuli [5,6]
- Performed **current density reconstruction (CDR)** of brain activity sources [7-11]
- Performed **speech perception-in-noise** testing [12,13]
- CDR patterns were analyzed within the entire subject group and **across groups of CI children exhibiting good vs. poor speech perception** [13]

Subject Demographic Characteristics

Subject Code	Age (Years)	Age at first CI (Years)	Age at Second CI (Years)	First CI Ear	Duration of First CI Experience (Years)	Duration of Second CI Experience (Years)
1	9.4	1.99	4.36	R	7.41	5.04
2	6.44	1.23	2.98	L	5.21	3.46
3[1]	13.79	8.42	13.18	R	5.37	0.61
4[1]	11.42	6.14	HA[2]	L	5.28	N/A
5	15.43	1.41	9.26	R	14.02	6.17
6	6.89	2.28	2.9	L	4.61	3.99
7	5.84	4.33	HA[2]	R	1.51	N/A
8	12.39	1.00	3.33	R	11.39	9.06
9	11.41	1.61	6.61	R	9.8	4.8
10	13.13	0.50	8.09	R	12.63	5.04

[1] Subjects had progressive hearing losses associated with diagnoses of enlarged vestibular aqueduct syndrome (EVAS). [2] Subject with hearing aid contralateral to cochlear implant.

References

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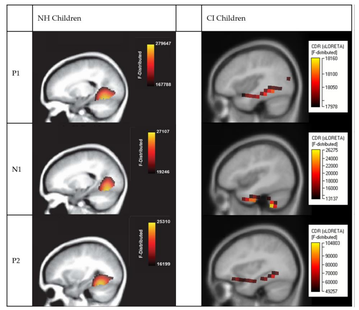
Results: Current Density Reconstruction

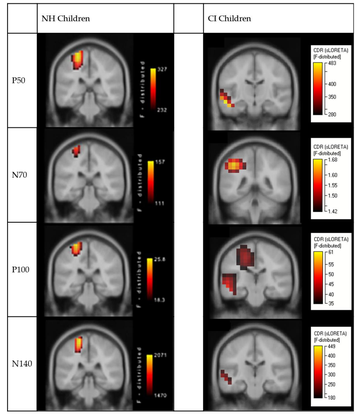
Evidence of Visual Cross-Modal Reorganization



Children with CIs demonstrate activation of temporal cortical regions in response to visual stimulus, compared to normal hearing (NH) children who demonstrate activation of occipital regions. This is suggestive of cross-modal reorganization by vision.

Figure 1. CDR images illustrating cortical activation underlying CVEP peak components P1, N1, and P2 on sagittal MRI slices in NH children (left panel; n=41, age range 5.87–14.53 years, mean age 10.32) [3] and in children with CIs (n=10; right panel)

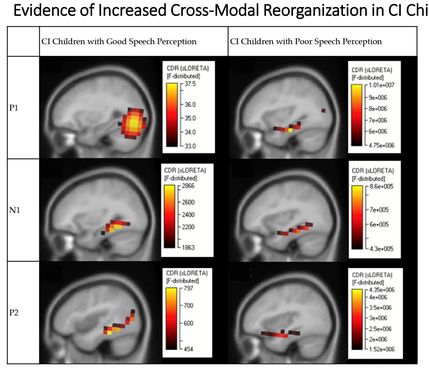
Evidence of Somatosensory Cross-Modal Reorganization



Children with CIs demonstrate activation of auditory temporal cortical regions in response to a somatosensory stimulus, compared to NH children who demonstrate activation of parietal regions. This is suggestive of cross-modal reorganization by the somatosensory modality.

Figure 2. CDR images illustrating cortical activation underlying CSEP peak components P50, N70, P100, and N140 on coronal MRI slices in NH children (left panel; n=35, age range 5.84-17.27 years, mean age 10.54) [4] and in children with CIs (n=10; right panel)

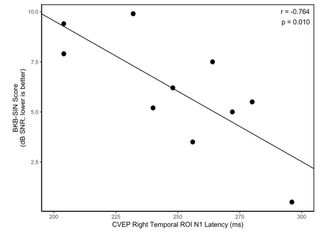
Evidence of Increased Cross-Modal Reorganization in CI Children with Poor Speech Perception



CI children with good speech perception show expected activation of occipital regions in response to a visual stimulus, while CI children with poor speech perception demonstrate cross-modal recruitment of temporal and frontal regions (suggestive of cross-modal reorganization by vision).

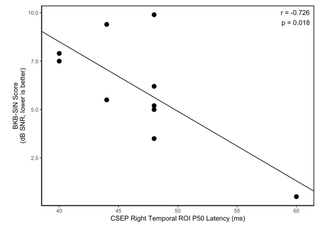
Figure 3. CDR images illustrating cortical activation underlying CVEP peak components P1, N1, and P2 on sagittal MRI slices in CI children with good speech perception (left panel; n=5, mean BKB-SIN score 3.9 dB SNR, mean age 10.7) and poor speech perception (right panel; n=8, mean BKB-SIN score 11.3 dB SNR, mean age 10.5)

Results: Relationship between Cross-Modal Reorganization and Speech Perception in Noise



CI children who had difficulty processing speech in noise with their implants (higher BKB-SIN score) showed more evidence of cross modal recruitment by vision (earlier CVEP latencies), as seen in previous studies [3].

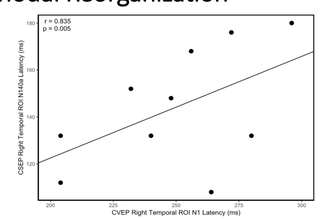
Figure 4. Scatter plot illustrating the correlation between BKB-SIN score and CVEP N1 latency in the right temporal ROI in children with CIs (n=10) Since BKB-SIN is a threshold test, a higher score reflects worse performance. Earlier CVEP latencies are considered a marker of visual CMR.



CI children who had difficulty processing speech in noise with their implants (higher BKB-SIN score) showed more evidence of cross modal recruitment by somatosensation (earlier CSEP latencies) consistent with previous studies [4].

Figure 5. Scatter plot illustrating the correlation between BKB-SIN score and CSEP P50 latency in the right temporal ROI in children with CIs (n=10). Since BKB-SIN is a threshold test, a higher score reflects worse performance. Earlier CSEP latencies are considered a marker of somatosensory CMR.

Results: Relationship Between Visual and Somatosensory Cross-Modal Reorganization



Children with CIs who showed greater visual cross-modal reorganization (as evidenced by earlier CVEP latencies) also showed greater somatosensory cross-modal reorganization (as evidenced by earlier CSEP latencies).

Figure 6. Scatter plot illustrating the correlation between CSEP 140a latency and CVEP N1 latency in the right temporal ROI in children with CIs (n=10)

Discussion

- **Cross-modal reorganization of auditory cortex** by visual and sensory modalities is evident in children with CIs and **is negatively associated with speech perception** using the cochlear implant
- **Positive correlation between visual and somatosensory cross-modal reorganization** suggests that the neuroplasticity in different sensory systems **may be interrelated**
- CI children with **good speech perception did not show recruitment** of frontal or auditory cortices during visual processing, while subjects with poor speech perception did, suggesting that **cross-modal recruitment may explain some underlying variability** in speech perception outcomes
- Findings reflect **widespread changes** in cortical networks in CI children that **may impact functional outcomes**