Long-term effects of deprivation and adverse input conditions on language development: Insights from children with cochlear implants

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BACKGROUND

Children with severe hearing loss or deafness are now regularly fitted with cochlear implants (CIs) to enable them to hear and thus gain access to spoken language. Although CIs are the most successful neuroprosthesis to date, technical limitations remain, such as reduced frequency resolution. Another important issue is the auditory deprivation that these children suffer at a very important stage of language development. The study of children with cochlear implants therefore represents a model of language acquisition under restricted conditions. Is brain plasticity sufficient to compensate for deprivation and reduced input? Which aspects of language acquisition are affected and how?

Research Questions:

(1) Do CI children process intonational phrases of complex sentences similar to TH peers? ➔ **ERP effect: closure positive shift (CPS)**

(2) Is the syntactic analysis in CI children guided by prosodic information? ➔ **ERP effects: N400 / P600**

METHODS

In an EEG experiment, we investigated semantic, syntactic and prosodic aspects of sentence processing in children with bilateral cochlear implants (median implantation age 20 months) and compared the data with typically hearing (TH) peers. The children listened to sentences with either two or three intonational phrases and performed a probe verification task. Furthermore, in a behavioral post-survey children reproduced some sample sentences used in the EEG study.

Participants

		TH Peers	CI Children
N		30	30
Hearing age (years)	**mean**	8,5	8,5
	median	8,1	8,1
	SD	1,8	1,8
	range	5,6-12,3	5,3-12,5
Chronological age	**mean**	8,5	10,4

Stimuli

(A) Correct prosodic phrasing (2 intonational phrases [IPhs]; intransitive verb)
[Der Trainer schwört Lisa zu JUBELN]$_{IPh1}$ [und die Fahne zu schwenken.] $_{IPh2}$
The coach pledges Lisa to cheer and wave the flag.

(B) Correct prosodic phrasing (3 intonational phrases [IPhs]; transitive verb)
[Der Trainer schwört] $_{IPh1}$ [LISA zu LOBEN] $_{IPh2}$ [und die Fahne zu schwenken.] $_{IPh3}$
The coach pledges to praise Lisa and wave the flag.

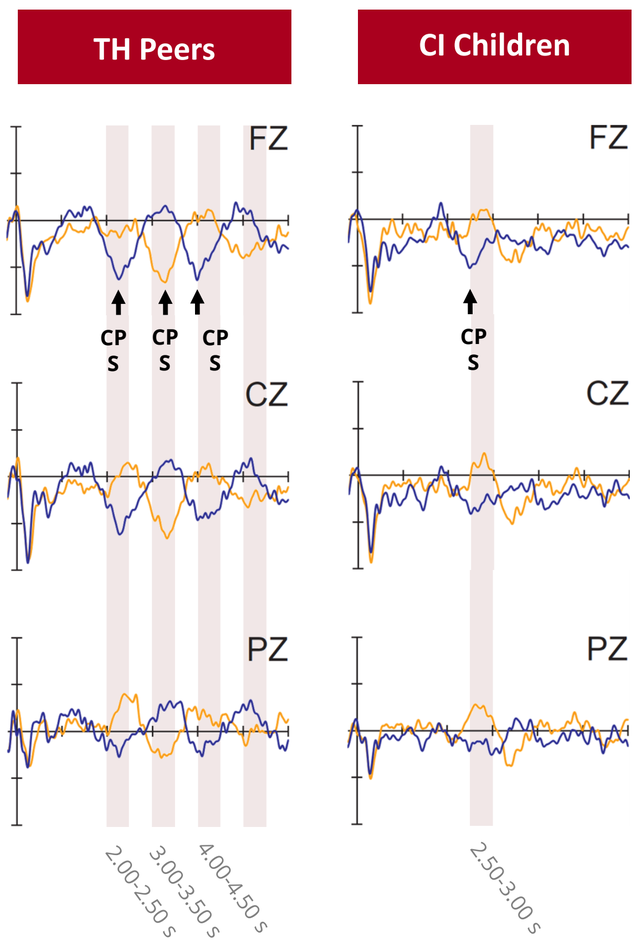
Cross splicing:

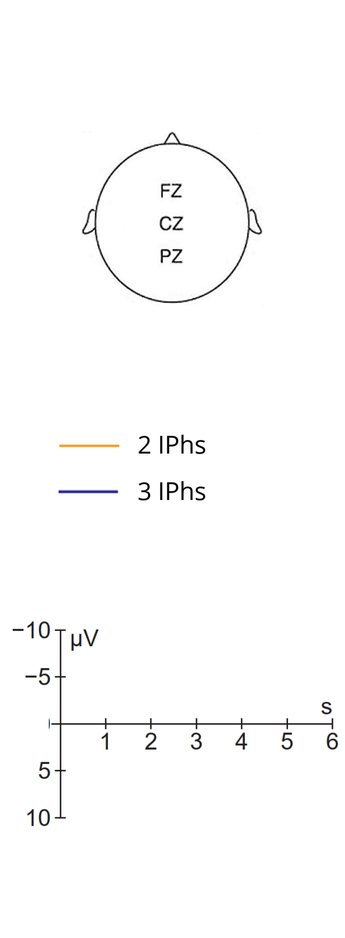
(C) Incorrect prosodic phrasing (prosody-syntax mismatch)
*[Der Trainer schwört] $_{IPh1}$ [LISA zu JUBELN] $_{IPh2}$ [und die Fahne zu schwenken.] $_{IPh3}$
The coach pledges Lisa to cheer and wave the flag.

EEG Recording and Analysis

- 19 Ag-AgCl Scalp electrodes referenced to mastoids; 512 Hz Sampling Rate
- Average relative to 200 ms preaverage baseline for: (1) 6 sec. beginning from sentence onset (CPS) and (2) 2.5 sec. beginning at the infinitive marker *"zu"* (N400/P600)

RESULTS





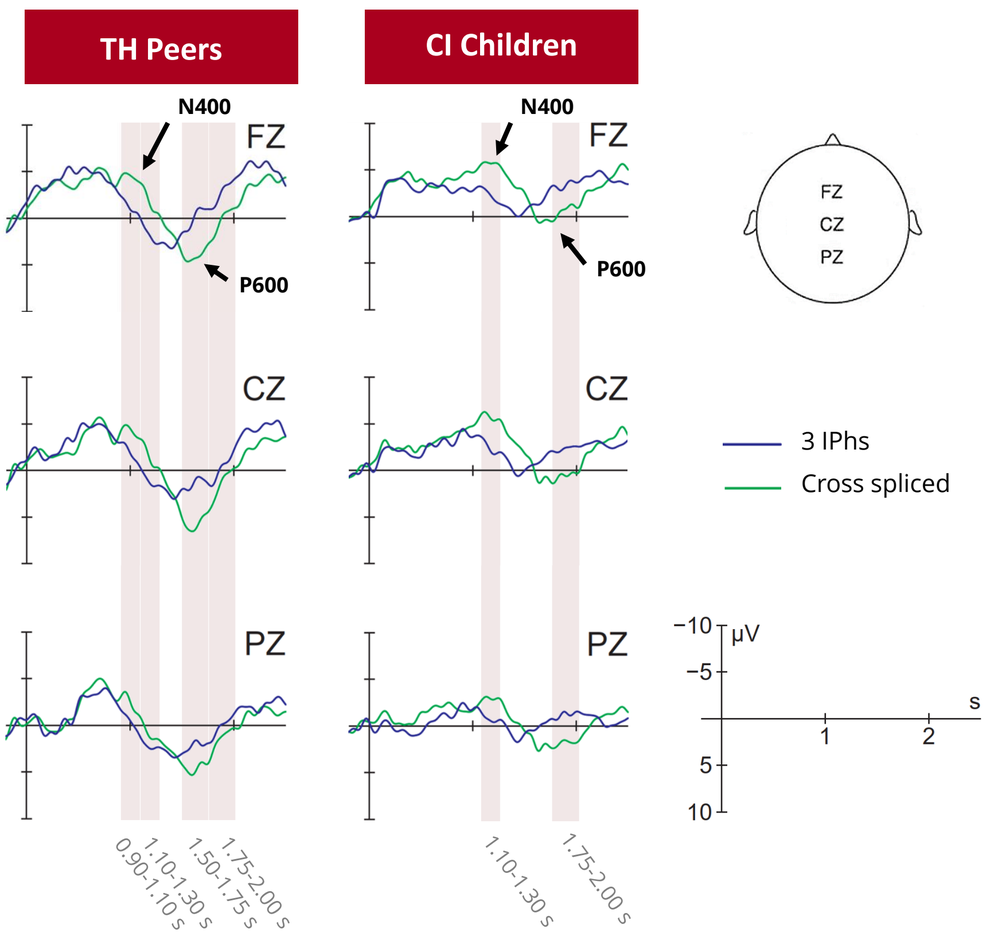


Fig. 1: **Processing of prosodic phrase boundaries.** ERPs averaged for 6 seconds beginning from sentence onset, with a baseline 200 ms before average onset. Significant time windows (p<.05) are marked.

Fig. 2: **Processing of prosody-syntax mismatch (garden path).** ERPs averaged for 2500 ms beginning on the infinitive marker *"zu"*, with a baseline 200 ms before average onset. Significant time windows (p<.05) are marked.

Post-survey: Sentence comprehension

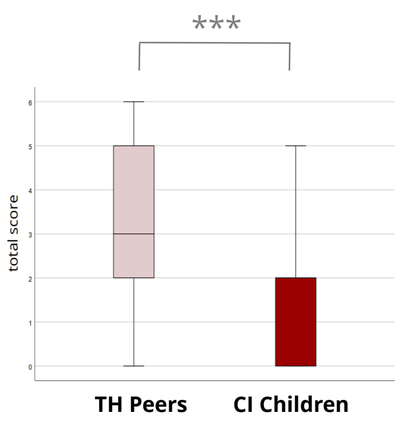


Fig. 3: Results of the behavioral judgement conducted after the EEG study in which children described the content of some sample sentences used in the prior experiment.

DISCUSSION

The data show that the unfavourable conditions (deprivation and physically adverse input) have a long-lasting effect on language acquisition. The prosodic structuring of a sentence shows clear deficits in the CI group as compared to TH peers. Prosodic cues were not efficiently used for prosodic phrasing in children with CIs. In sentences consisting of three Iphs, only the first phrase boundary, but not the second boundary elicited a (delayed) CPS. This was confirmed by the behavioural data. Here it was shown that speech comprehension for these sentences was significantly worse than for the TH peers (who were even younger in chronological age). Interestingly, however, the CI children were guided in their syntactic analysis by sentence prosody at the beginning of the sentence, similar to the TH children. In both groups an N400/P600 pattern was evoked, similar to adults (cf. Steinhauer et al., 1999), although the effect was somewhat delayed in the CI group. This shows that CI children also use prosodic information for syntactic structuring. Taken together, all prosodic effects were much weaker and observed later than in TH peers, demonstrating that the processing of long and complex sentences is a major challenge for hearing impaired children.

LITERATURE

Steinhauer, K., Alter, K., & Friederici, A. D. (1999). Brain potentials indicate immediate use of prosodic cues in natural speech processing. Nature Neuroscience, 2(2), 191–196. https://doi.org/10.1038/5757

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