From syllables to words: Language perception and language acquisition of young children with cochlear implants

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Background

The cochlear implant (CI) is a neuroprosthetic device that provides auditory sensation to otherwise deaf individuals. It does so by stimulating the auditory nerve directly thus by-passing any dysfunctional parts of the inner ear. Language acquisition is one key motivation for pediatric cochlear implantation, yet we still know little about the developing language network of young cochlear implanted children. The objective of the following studies was to assess which auditory features are available to deaf children in the first months following implantation and what effect a delayed auditory access to language has on the overall language development of young children.

Methods

Participants:

- Infants and children implanted bilaterally before the age of four years (9 – 50 months)

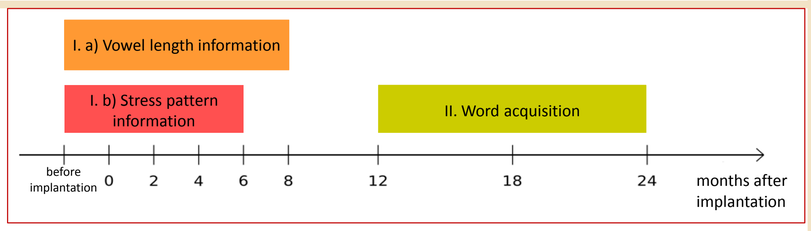


Fig. 1. Timeline of the three studies within the auditory age (time with CI) of implanted children.

3 longitudinal studies:

I. **Perception of word boundaries**: basic markers of word boundaries that enable typically hearing children to segment the speech stream and identify single words
   a) **Vowel length** */ba/* vs. */baa/*
   b) **Stress pattern** */baaba/* vs. */babaa/* (trochaic pattern baaba being the predominant stress pattern in German)

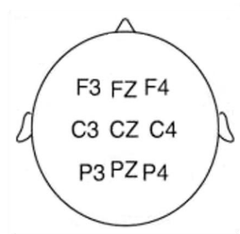
→ *Oddball paradigm* with 1200 trials (standard trials: 83%, deviant trials: 17%). A *Mismatch Response* is elicited if and whenever a deviance is perceived.

II. **Word acquisition**, i.e. establishing fixed word-object relationships; *picture-word-matching paradigm*, visual stimulus: picture of simple object, parallel auditory stimulus: spoken word; 88 trials per condition (congruent vs. incongruent).

→ If word-object relationship is established, incongruent picture-word pairings (i.e. wrong label) will elicit an N400 effect.

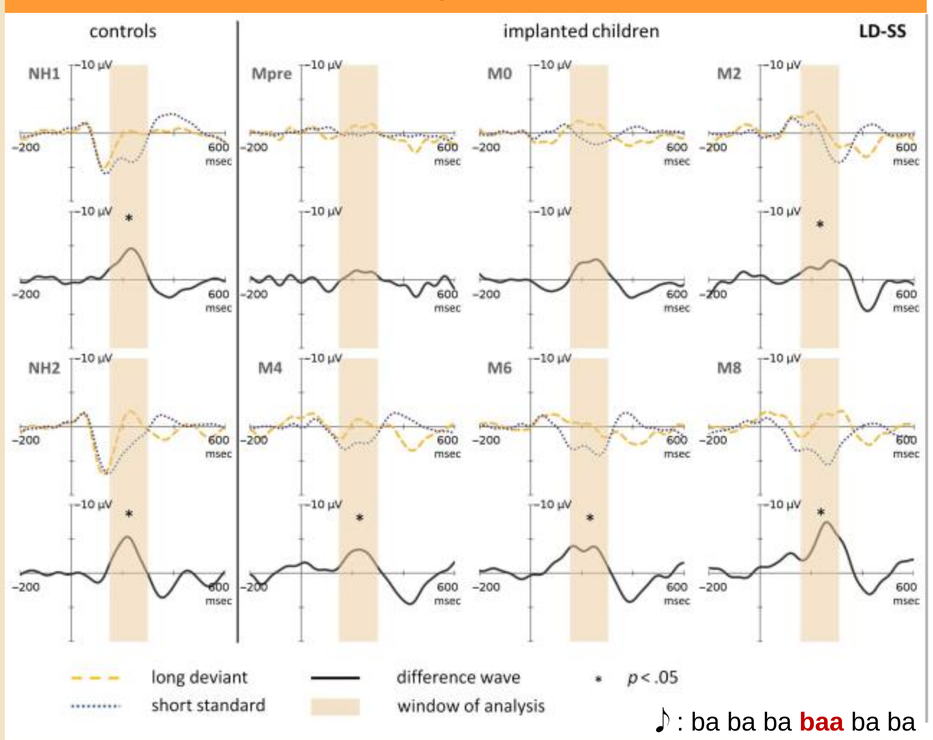
EEG settings

- 9 scalp electrodes
- 2 mastoid electrodes
- 4 ocular electrodes
- 500 Hz sampling rate



I. Perception of word boundaries

a) Vowel length information



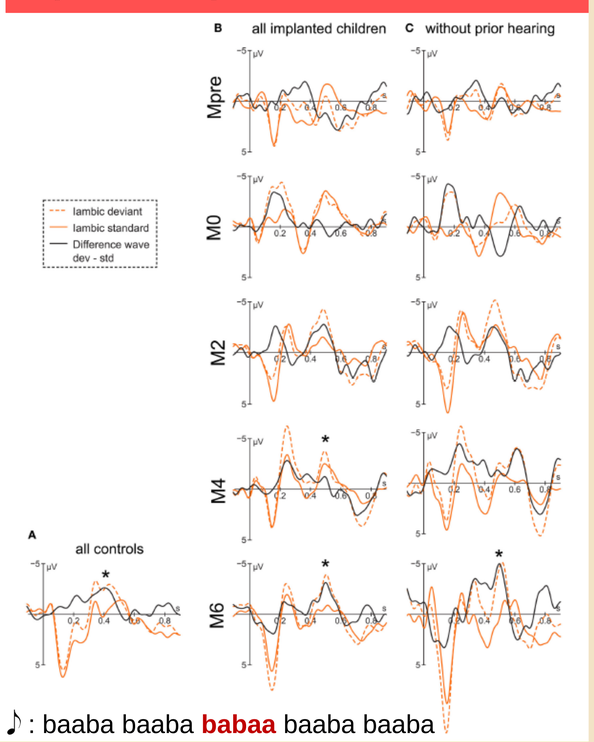
♪ : ba ba ba **baa** ba ba

Congenitally deaf children display a mismatch response (i.e. perceive vowel length differences) already after 2 months of hearing experience.

Children with acquired deafness need 4 months of hearing experience with the CI to identify stress patterns as native or non-native. Congenitally deaf children display the effect after 6 months.

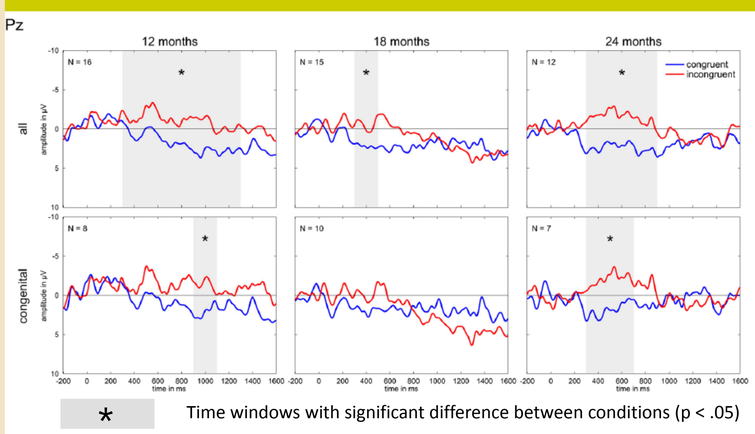
Adaptation to the new sensory modality is relatively fast but not immediately present after activation of the CI. Some minimum time of sensory experience seems to be required.

b) Stress pattern information



♪ : baaba baaba **babaa** baaba baaba

II. Word acquisition



* Time windows with significant difference between conditions ($p < .05$)

Fig. 2. N400 effect (incongruent trials more negative voltage than congruent trials) present after 12 months *even in congenitally deaf children*. Fixed word-object relationships are thus evident 2 months earlier than in typically hearing children.

Implanted children show evidence for word acquisition after less language exposure time (12 months) than typically hearing children (>14 months).

Implanted children are older when first exposed to oral language with more mature cognitive faculties (attention, memory, …). For word acquisition this seems to compensate the delayed language acquisition onset.

Characteristically, a subgroup of implanted children did not develop any signs of word acquisition even after 2 years of language exposure. Seven out of nine had a late diagnosis of some cognitive impairment (not evident at the begin of the study) corroborating our assumption that development of other cognitive domains compensates the late and poor linguistic input.

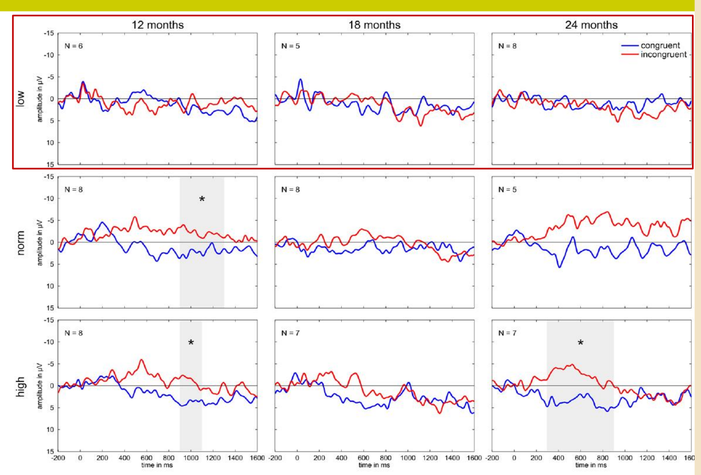


Fig. 3. Exception: Children that perform below the normative range in a later language test do not display an N400 effect even after two years of hearing with the CI.

Conclusion

- The perception of basic auditory features is developed in a comparable time frame as in typically hearing children (counting from hearing onset). Word segmentation cues are thus available fast if not immediately as some sensory experience is necessary.
- By contrast, word acquisition is influenced to a greater amount by cognitive maturation which can offset some of the disadvantages of late language exposure and the poorer input quality. Importantly, children with poor language outcomes mostly also had cognitive impairments and their EEG data differed already after 12 months of hearing experience for their implanted peers, i.e. one year before tested with formal language tests.

Discussion points for comparing music and language

We completed a study series on how deaf children perceive auditory features that are linguistically relevant and how this influences language acquisition. Similar features like stimulus length and stress/rhythm are also present in music. In an ongoing study we look at how such features are processed by implanted children in a musical context (oddball paradigm with deviant changes of tones in intensity, length, rhythm, pitch and timbre). Which features are most easily accessible with the CI and do we see a relationship between performance with musical stimuli and performance with linguistic stimuli/later language performance?

References

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