Cortical processing of musical and speech sounds in early-implanted children - role of musical activities

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Introduction

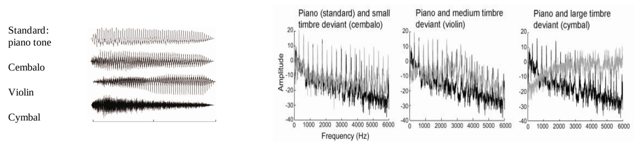
•Musical experience can enhance auditory cortical function in normal hearing (NH) children.
•Our behavioural experiments show connections between musical activities and auditory perception in CI children.

- Is the cortical processing of musical and speech sounds different between implanted and normal hearing children?
- Does musical experience affect CI children's cortical sound processing?

Methods

•22 children with early unilateral CI aged 4 to 14 and 22/25 age-matched NH children.
•Nine CI children participated in musical activities outside of the home.
•Two measurement points for event related potentials (ERPs) 14-16 months apart (T1, T2).
•Biosemi Active2 system/64 channel. Additional electrodes on left and right mastoid and right eye. Common reference: nose.
•Stimuli presented through 2 loudspeakers at 45° each side of the subject.
•Passive task: children watched a silent movie.
•Median averaging: CI artefacts removed by Independent Component Analysis (ICA).

Experiment 1: Natural music sounds



Standard: natural piano tone. F0 295 Hz, duration 200 ms, SPL 60 dB NH/70 dB CI children. Duration of experiment 37 min.

Expt 1	
Pitch	312, 351, 441 Hz
Timbre	Cembalo, violin, cymbal
Duration	-25, -100, -150 ms
Intensity	Increment or decrement of 3, 6, 9 dB
Gap	5, 40 , 100 ms

Experiment 2: speech

Standard: Pseudoword /tatata/ - 480 ms duration: female speaker.
Middle syllable: F0 169 Hz, formants 700; 1476; 2700; 3870 Hz
Vowel duration 79 ms, vowel intensity 67 dB. Duration of experiment 30 min.

Expt 2	Deviants applied to middle syllable:
Pitch	+ 15% (194 Hz) or + 50% (250Hz)
Vowel timbre	/o/; formants: 560; 1240; 2750; 3900 Hz
Duration	+80 ms
Intensity	+ 6dB, - 6dB
Gap	100 ms gap before mid syllable

EEG measures:

P1: Reflects processing at thalamo-cortical level and primary auditory cortex (Sharma et al., 2007).
MMN = Mismatch negativity: reflects pre-attentive detection of change (Näätänen et al., 2007).
P3a : associated with involuntary switching of attention to novelty (Näätänen, 1992; Alho et al., 1997).

Results from Experiment 1.

P1: Smaller and earlier in CI ($p < 0.001$)
Perhaps due to less well developed auditory cortex? Hypersynchronization (Kral et al., 2009)? Electric stimuli?
No difference between 1st and 2nd measure for P1 in CI children.

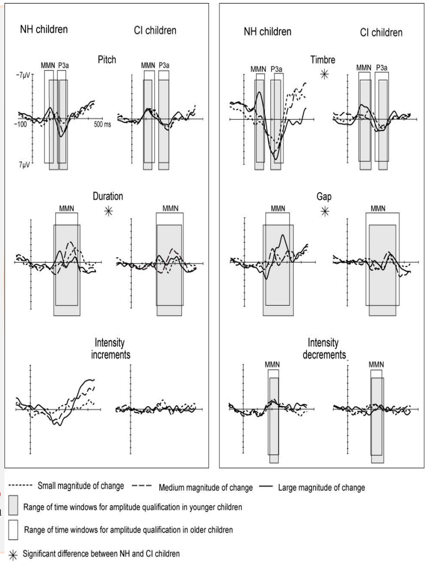
MMN:
Timbre: Less accurate discrimination in CI (MMN cymbal smaller, p = 0.003; later, p = 0.017)
Duration: (175 ms and 100 ms ; MMN smaller, p = 0.004; later, p = 0.007)
Gap: (40 ms gap MMN later , p = 0.001).

Pitch, intensity: No significant difference between CI and NH groups in MMNs for pitch and intensity decrement deviants.
MMN and P3a for pitch were significant in CI children at T1 and T2.

Possible that pitch deviant responses in CI children arise from loudness cues (Pjil, 1997) .

P3a: Less accurate attention switching to changes in timbre in CI children (P3a smaller, p < 0.001).

Intensity increment: Waveforms differed between groups; may reflect effect of AGC?



Effects of Music experience in CI group

Pitch: smaller MMN (p= 0.006) and P3a (p = 0.036) in children in musical activities
It seems possible that children with music experience are less influenced by cues incidentally associated to changes in F0.

Timbre: MMN for changes in timbre (especially from piano timbre to violin) occurs earlier in time in CI children with music experience (p= 0.038).
Duration: MMN occurs earlier in CI Children with music experience (p = 0.045).
CI – children with music experience show enhanced auditory discrimination on these dimensions.

Results from Experiment 2.

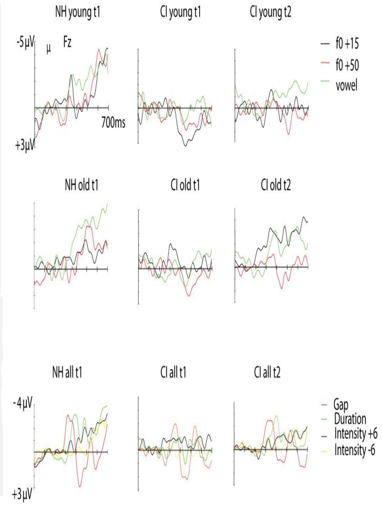
At T1 CI children show significant changes in the neural response to pitch and vowel quality deviants. However where MMN responses might be expected the observed neural change has a positive polarity.

In older CI children responses at T2 to pitch and vowel quality deviants begin to look more similar to NH group – the MMNs are significant for vowel and 15% pitch deviant.

P1: Smaller in CI children ($p < 0.001$).
No differences in latencies.

Duration: CI children smaller MMN than NH (p = 0.033).

Gap 100ms: no differences between groups in MMNs.



Comparison between test points in CI children

P1: Became larger at second test point (p= 0.018), especially at middle electrodes (p<0.001).
Pitch+15% MMN responses became larger at second test point (p = 0.003) and were larger in older children (p = 0.008).
Pitch+50%: Positive response weakest at right electrodes (p = 0.009) - lateralization to left.
Gap: MMN response was weakest at right electrodes (p = 0.019) - lateralization to left.
Intensity: + 6 dB: at second measure MMN became larger on right (p = 0.013).

Effects of music experience

Pitch +15%: While MMN in CI children in general tended to be largest at middle and left electrodes, in the music experience group, MMN was significantly smaller at right consistent with stronger lateralization to left (p = 0.001).

Suggests that music experience may enhance specialization of left auditory cortex for pitch (Zatorre and Gandour, 2007; Ono et sl., 2011).

Duration: MMN was earlier in older CI children participating music: however in CI children not engaged in music, MMN was earlier in younger children (p = 0.040) .

Conclusions

1. Stimulus matters: P1 responses consistent with less developed auditory cortex in CI children in both experiments, and responses to pitch change in CI children are similar to normal hearing group for piano tones, but not for speech.
2. At the neural level, even young CI children seem to discriminate correlates of pitch and timbre. Our behavioural experiments show that some CI children learn to hear pitch changes in speech, particularly if they are exposed to music.
3. Musical activities seem to enhance cortical processing of some features of piano tones (timbre, duration) – while effects of music experience on cortical processing of pitch remain unclear.

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