Neural entrainment to rhythmic tone sequences in 6-7 year old children

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Background

- The brain resonates to music at multiple time scales via entrainment of oscillatory networks to the regular beat of the music
- The time course of desynchronization and rebound of induced beta-band activity (15-25 Hz) adjusts to stimulus tempo (Cirelli et al., 2014)
- Evoked short-latency gamma-band (20-60 Hz) activity (GBA) depends on tone omission or presence and intensity, whereas induced GBA remains unaffected even in the absence of the expected stimulus tone (Snyder & Large, 2005)
- Phase coupling between auditory and movement related EEG activities and selective enhancement of auditory related activities contralateral to the moving hand during tapping to isochronous tone sequences suggests dynamic coupling of sensory and motor neural processes (Nozaradan et al., 2015)

Methods

Participants

Twenty-two children (8 girls, mean age: 6.5 years, SD = 0.51). Children were all right handed and had no music training prior the experiment.

Run1

Stimuli

3 isochronous sequences of a 262 Hz pure-tone with 3 different inter-onset-intervals (IOIs): 390 ms, 540 ms, 780 ms.

Task

Passive listening while watching a silent movie

Run2

Stimuli

30 blocks of a 262 Hz pure-tone sequence with alternating loud-soft accent pattern with 390 ms IOI. One-third of the accent pattern contained omission of the first (loud) tone.

Task

Passive listening while watching a silent movie

Run3

Stimuli

6 sequences of a 33 s duration 333.33 Hz pure-tone amplitude modulated at 2.4 Hz.

Task

Tapping on every second beat (1.2 Hz)

EEG recording

EEG data were acquired using BrainAmp MR amplifiers and an actiCap system (Brainproducts GmbH., Munich, Germany). 64 active scalp electrodes were placed according to the 10–10 international electrode system. Electrode impedances were kept below 10 kΩ and data were sampled at 1000 Hz.

Results

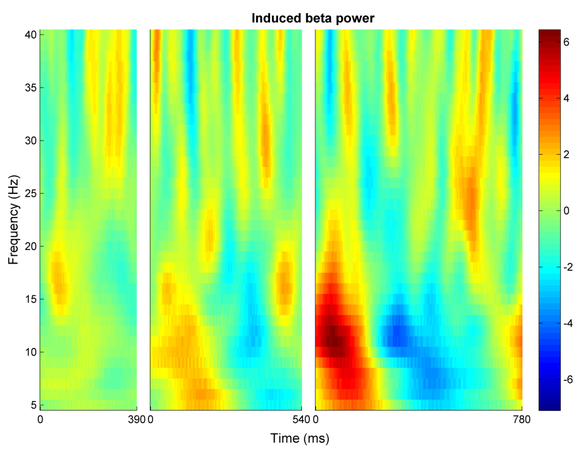

Fig. 1. *Time-frequency spectogram of percent power changes on electrode cluster FC5, C5, FT7 for three tempo conditions (390, 540, 780 ms from left to right).*

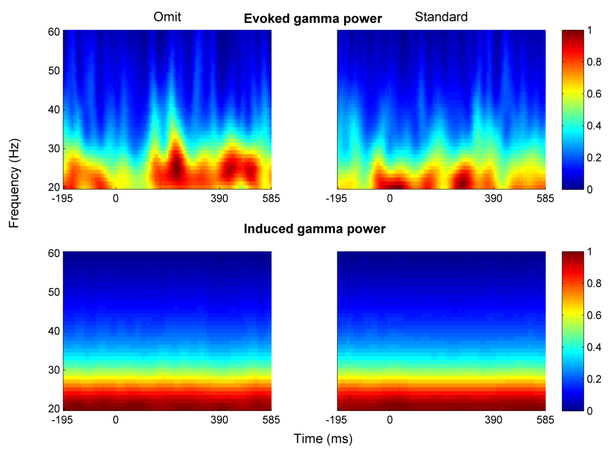

Fig. 2. *Induced and evoked GBA. The omit condition contains an absent loud tone at 0 ms and a present soft tone at 390 ms with normalized plots of TF induced and evoked power as a mean across 15 fronto-central electrodes (Fz, F1/2/3/4, FCz, FC1/2/3/4, Cz, C1/2/3/4). The standard condition contains both a loud and a soft tone.*

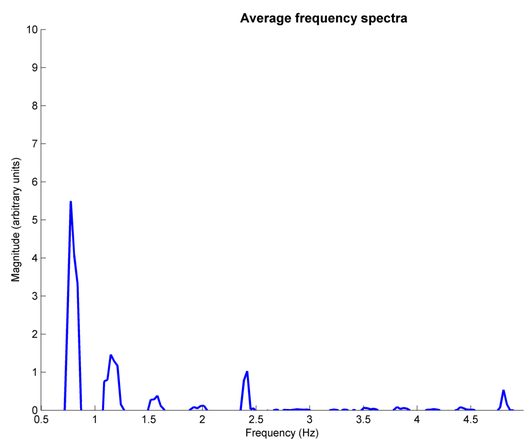

Fig. 3. *Group-level average frequency spectra of the noise-subtracted EEG amplitude signals.*

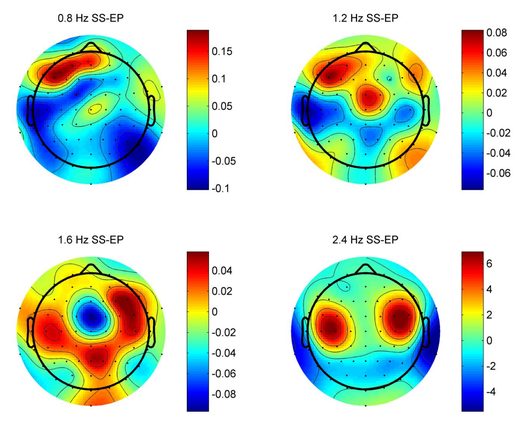

Fig. 4. *Topographic maps (group-level average current scalp density) of 0.8-,1.2-,1.6- and 2.4 Hz SS-EPs.*

There were main effects of tempo on the latency of the maximum desynchronization, $F(2,42) = 10.6$, $p < 0.001$, and rebound, $F(2,42) = 70.1$, $p < 0.001$. *Post-hoc* analyses revealed that desynchronization and rebound occurred the earliest for the fastest tempo, later for the medium tempo and the latest for the slowest tempo.

There was a significant interaction between GBA type and the loudness of the tone both in power, $F(1,21) = 9.36$, $p = 0.006$, and in latency, $F(1,21) = 9.12$, $p = 0.007$. Larger responses occurred for the soft tone for the evoked GBA, whereas responses were larger for the loud tone for the induced GBA. Furthermore, the latency of the loud and soft tones fell closer to each other for the evoked compared to the induced GBA.

The auditory beat elicited an SS-EP at 2.4 Hz with a harmonic at 4.8 Hz, and the tapping elicited an SS-EP at 1.2 Hz. The two additional SS-EPs at 0.8 and 1.6 Hz could be the result of subjective metrical percept of a ternary meter of the beat frequency and its first harmonic. There was no phase coupling between the auditory and motor related EEGs.

Conclusions

Neural entrainment to rhythmic tone sequences in 6-7 year old children shows similar characteristics to adults. The most pronounced responses were observed in the low beta-band (15-20 Hz). There seemed to be precursors of entrainment in short-latency GBA, but there was no evidence for coupling between auditory and motor processes during tapping to the beat. The lack of dynamic coupling could be due to the difficulty of the tapping task or its existence depends on training or age.

References

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Acknowledgments

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