UNIVERSITY
CHILDREN'S HOSPITAL ZURICH
Children's Research Center CRC
The hospital of the Eleonore Foundation

Universitäts-
Kinderspital Zürich – Eleonorenstiftung
Steinwiesstrasse 75
CH-8032 Zürich
www.kispi.uzh.ch

Effects of phase-targeted auditory stimulation on non-REM sleep EEG activity in healthy children

Melanie Furrer[1], Veronika Gambin[1], Clara Wehlage[1], Gina Strähler[1], Sven Leach[1], Sara Fattinger[1], Reto Huber[1,2]

1. Child Development Center and Children's Research Center, University Children's Hospital Zurich, University of Zurich, Zurich, Switzerland
2. Department of Child and Adolescent Psychiatry and Psychotherapy, Psychiatric Hospital Zurich, University of Zurich, Zurich, Switzerland

Introduction

- Non-rapid eye movement (NREM) sleep EEG oscillations (see Fig. 1B) can be modulated by phase-targeted auditory stimulation (PTAS). [1],[2],[3]
- In young healthy adults…
  - … down-PTAS, targeting the down-phase of slow waves (Fig. 1), with ON-OFF windows evokes K-complex like responses (initial increase of delta power followed by an increase in sigma power) after isolated stimuli (long inter-stimulus interval). [2]
  - … continuous down-PTAS leads to a decrease in slow-wave activity (delta power 1 – 2 Hz). [3]
- K-complex generation depends on thalamocortical connections, while delta waves presumably are generated by corticocortical synchronization processes. [4]

Aims

- Do children show a K-complex like response after isolated stimuli (long inter-stimulus interval)?
- Do children show decreased delta power after continuous stimuli (trains of short inter-stimulus intervals)?

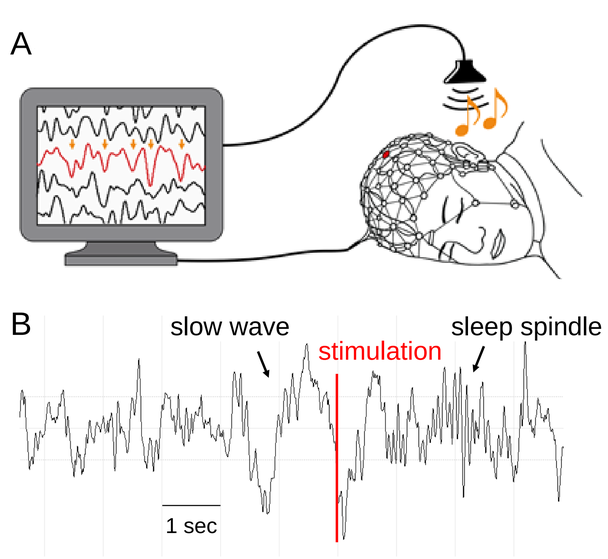

Fig. 1. Phase-targeted auditory stimulation (PTAS)
A) Setup of PTAS, adapted from [3]
B) Example of a 10 sec NREM sleep EEG. Stimuli are phase-locked to the down-phase of slow waves.

Results

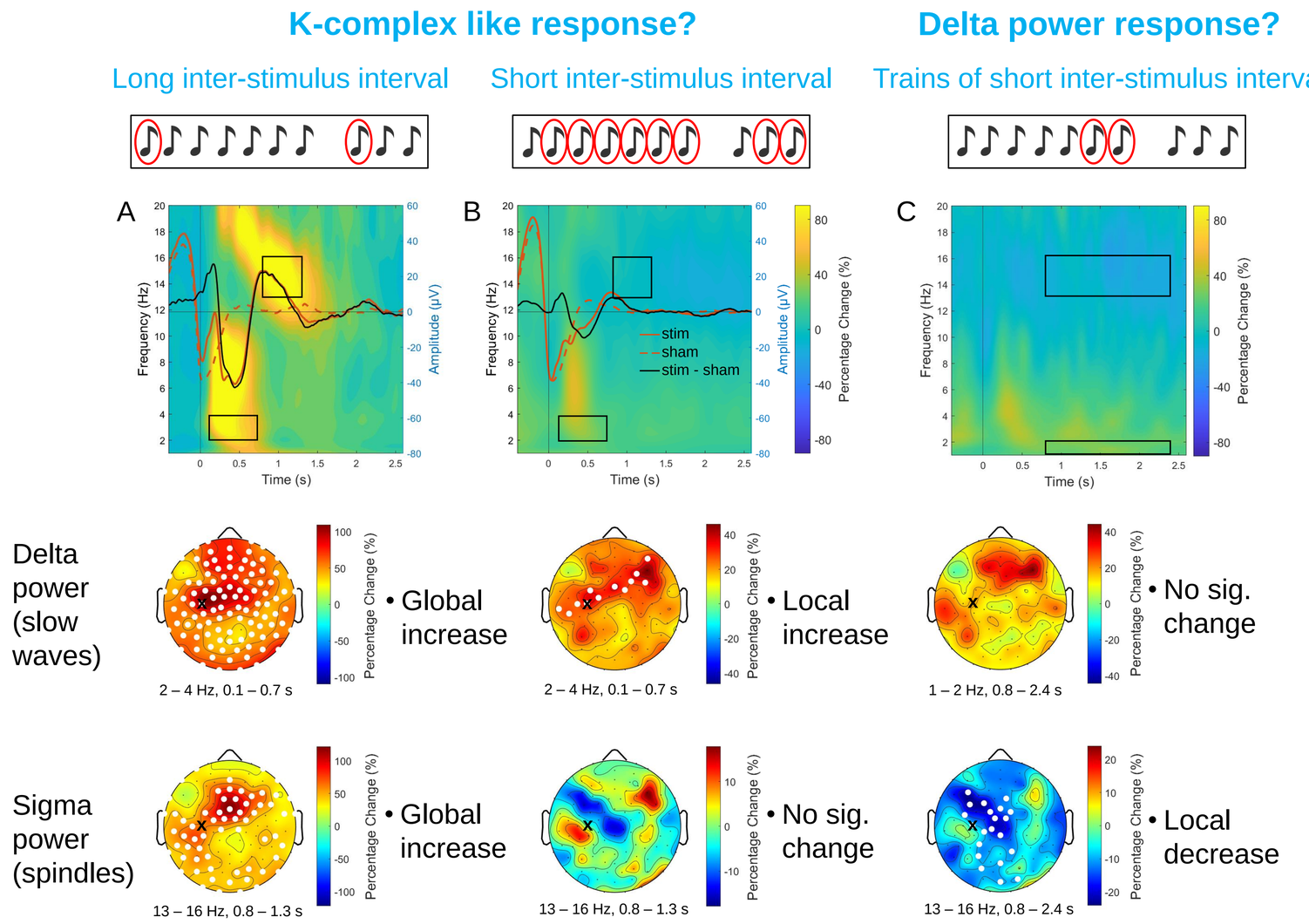

Fig. 2. EEG response to PTAS.
Data are time-locked to the stimulus (0 s) and averaged across trials and participants (n = 6). **A**: All trials with a long inter-stimulus interval (ISI > 3 s). **B**: All trials with a short ISI (< 1.5 s). **C**: All trials with trains of at least 6 stimuli with ISIs < 1.5 s.
First row: Spectral power change (stim vs. sham) and averaged EEG (right y-axis) of electrode FCz. Black boxes indicate time windows and frequency ranges across which power was averaged for topographical representations.
Second and third row: Topographical representations of power change. Significant electrodes (paired t-test) with a cluster size of ≥ 6 marked in white. Stimulation electrode (C3) marked with a cross (x).

Methods

Participants

- 6 healthy children (mean age: 9 y; range: 7.4 – 12.5 y; 2 female)

Sleep EEG recordings

- High-density (128 electrodes)
- Two nights (one stim, one sham)

Phase-targeted auditory stimulation (PTAS)

- Pink noise, ~ 50 dB
- Time-locked to the down-phase of slow waves detected by a central electrode (C3)
- ON-OFF window design (16 s ON, 8 s OFF)
- During NREM sleep

Conclusions

Preliminary analysis of a small dataset indicates that the effect of PTAS on NREM sleep EEG activity in children shows similarities, but also differences compared to adults:

- As adults, **children show a K-complex like response** to PTAS after isolated stimuli.
- In contrast to adults, **children do not show a decrease in delta power** (slow-wave activity) after continuous stimulation.
- Even with short inter-stimulus intervals and after trains of stimuli, delta power tends to be increased.
- Unexpectedly, children show a decrease in sigma power (sleep spindles) after continuous stimulation.

→ Age-dependent differences in corticocortical synchronization processes in response to PTAS?

References

[1] Ngo, H.V., Martinetz, T., Born, J., Mölle, M. Auditory closed-loop stimulation of the sleep slow oscillation enhances memory. Neuron 78, 2013.

[2] Leach, S., Krugliakova, E., Sousouri, G. et al. Acoustically evoked K-complexes together with sleep spindles boost verbal declarative memory consolidation in healthy adults. Sci Rep. 14, 2024.

[3] Fattinger, S., de Beukelaar, T., Ruddy, K. et al. Deep sleep maintains learning efficiency of the human brain. Nat Commun 8, 2017.

[4] Siclari, F., Bernardi, G., Riedner, B. A. et al. Two Distinct Synchronization Processes in the Transition to Sleep: A High-Density Electroencephalographic Study. Sleep 10, 2014.

Acknowledgements

Swiss National Science Foundation

Contact

melanie.furrer@kispi.uzh.ch