Influence of Slow Oscillating Transcranial Direct Current Stimulation (so-tDCS) on Electroencephalogram (EEG) and Cognitive Performance

Isabella von Mengden, Carmen Garcia, Martin Glos, Christoph Schöbel, Ingo Fietze, Thomas Penzel

Interdisciplinary Center for Sleep Medicine, Campus Charité Mitte, Berlin

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Introduction

Recent research [Kirov et al., 2009] has shown that transcranial slow oscillating stimulation increases EEG power in slow oscillations at frontal EEG positions as well as power in the theta and beta frequency band equally distributed across electrode sites. While applying stimulation during learning an improvement of memory performance can be observed. Enhancing the excitability of the prefrontal cortex (PFC) by means of anodal tDCS will presumably result in improved working memory function [Levy & Goldman- Rakic, 2000].

Primary endpoint of the study is an increase in slow oscillation (0.4-1.2Hz) power, at F7, F8 and Fz, as well as on theta (4-8Hz) and beta (15-25Hz) power across electrode sites. Secondary it is hypothesized that stimulation enhances cortical excitability in PFC, resulting in increased cognitive performance (indicated in improved Digit Span, DSST and PVT test results).

Material and Methods

Study design: Randomized, sham controlled, double-blind cross-over trial

Subjects: 30 healthy individuals divided in three groups at 10 subjects each

Procedure: See Figure 1 and 2

Stimulation: Anodal sinusoidal tDCS of 0.75Hz and 250µA; anodes F3 and F4, cathodes mastoid; stimulation duration 30minutes (5 blocks at 5minutes, one minute break in between). See also Figure 3 and 4

Tests: PSQI, HADS, ESS, AAT, KSS, PVT, Digit Span, DSST

EEG: Fz, Cz, Pz, C3, C4, P3, P4, F7, F8, T3, T4 , EMG, EOG, ECG

Statistics: Program PASW ® Statstics 18, dependent t- tests for paired samples

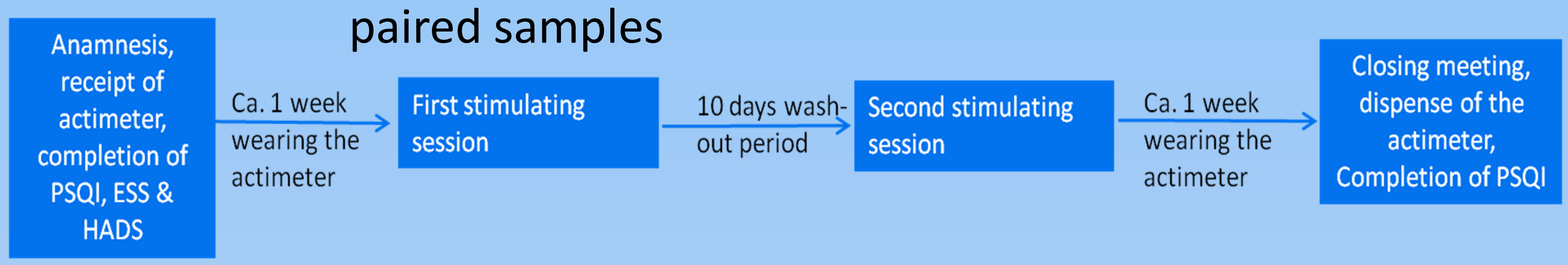

Figure 1: Overall procedure of the study

8:00am	Arrival of subjects
8:00- 9:30am	Attaching electrodes (EC2 gel)
9:30- 9:35am	Start of EEG recording, Impedance test
9:35- 9:45am	PVT test
9:45 – 10:05am	Karolinska Sleepiness Scale (KSS) Digit Span Digit Symbol Substitution Test (DSST)
10:05-10:10	Second impedance check, Bio-calibration
10:10- 10:22am	Alpha Attenuation Test (AAT) 2min eyes closed 2min eyes opened 2min eyes closed 2min eyes opened 2min eyes closed 2min eyes opened
10:22-10:30	Attaching stimulating electrodes (wet sponges)
10:30- 11:00am	**Transcranial slowly oscillating stimulation (tSOS)**
11:00-11:05	Removal of stimulating electrodes
11:05-11:17am	AAT
11:20- 11:30am	PVT
11:30- 11:50am	KSS Digit Span DSST
11:50am	Stop of EEG recording, removal of electrodes

Figure 2: Procedure for first group (one stimulating session pre day)

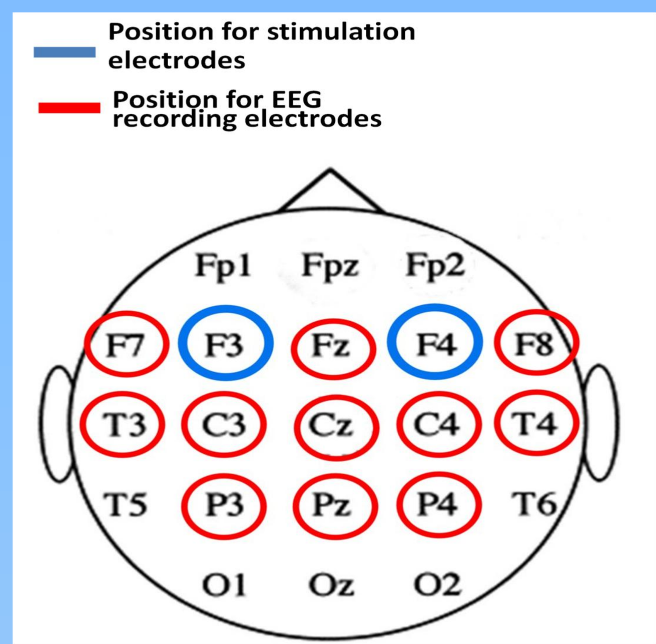

Figure 3: Blue circles indicate positions for stimulating electrodes. Red circles for recording EEG electrodes.

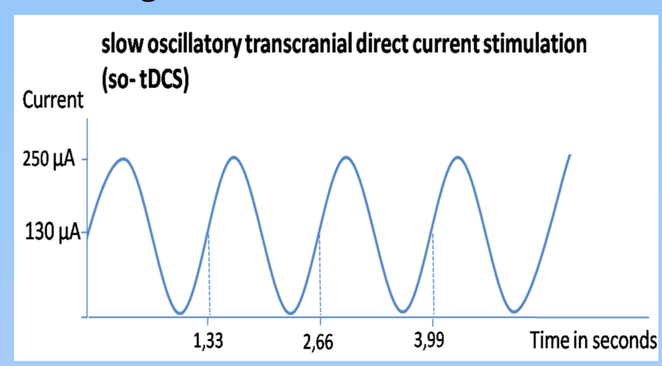

Figure 4: Stimulation signal

Results

Subjects: 6 subjects out of group 1

Significance: *p<.05; **p<.01

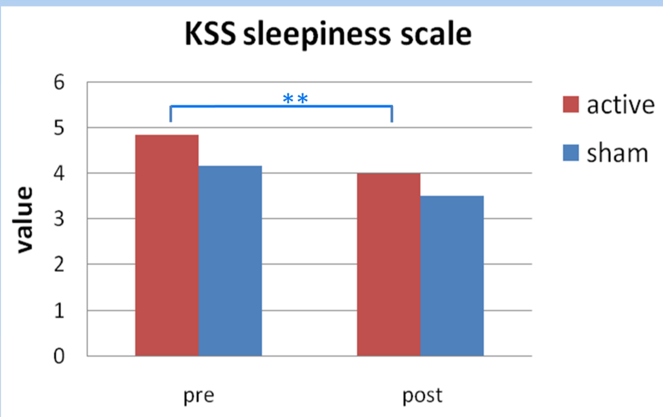

Figure 5: Significant difference in sleepiness among pre and post only in active condition

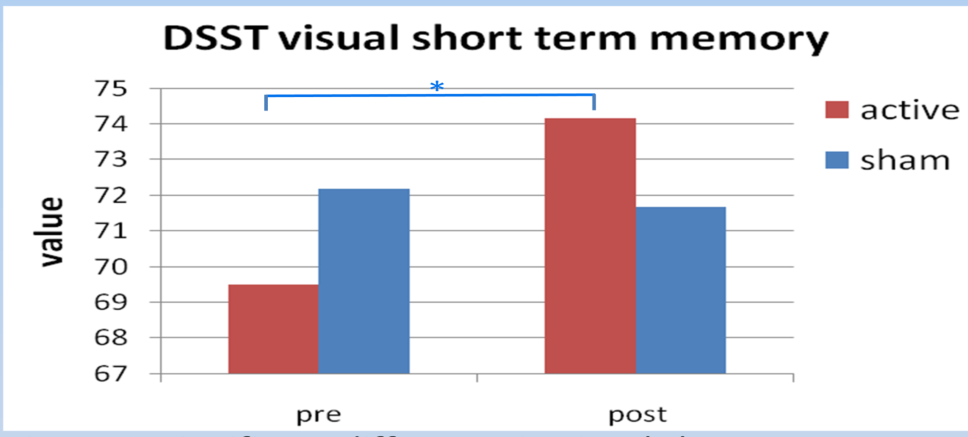

Figure 6: Significant difference in visual short term memory among pre and post only in active condition

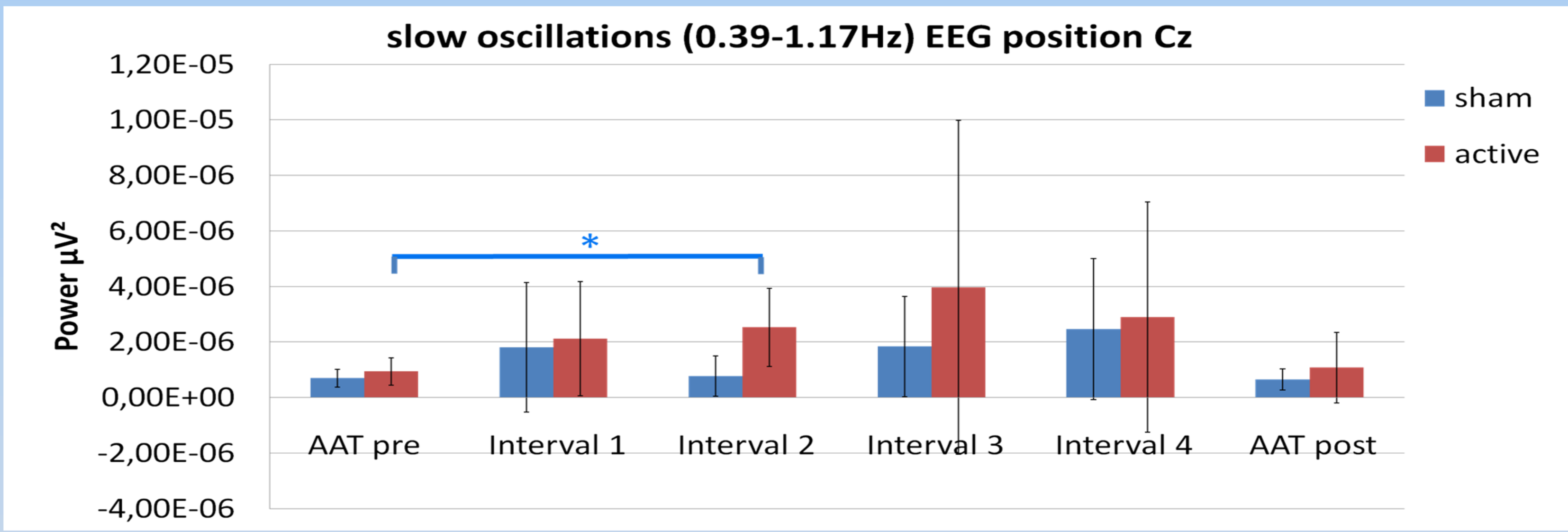

Figure 9: Significant difference in slow oscillation power (position Cz) among AAT pre and Interval 2 only in active condition

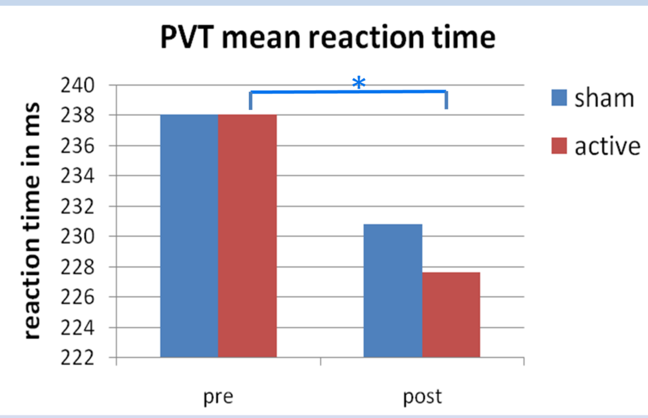

Figure 7: Significant difference in reaction time among pre and post only in active condition

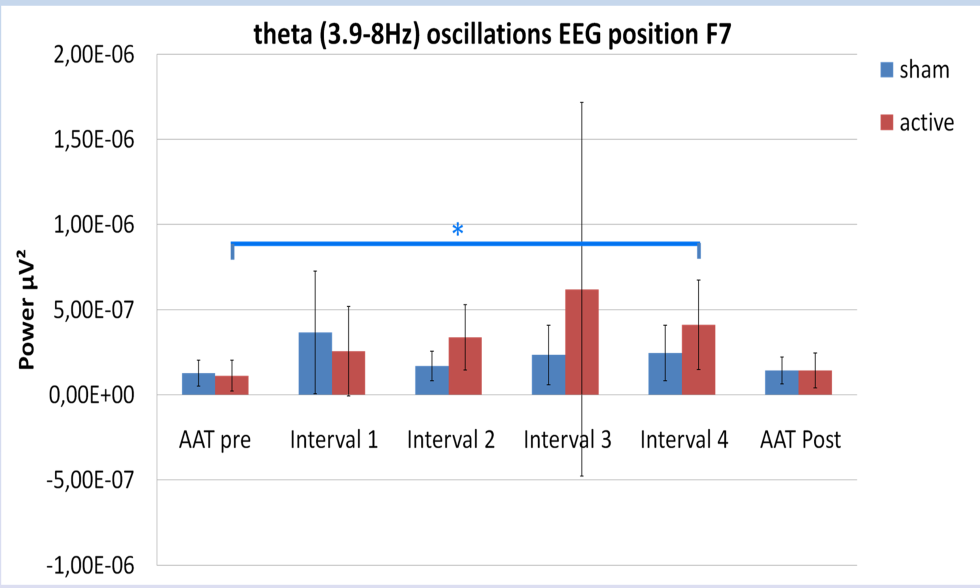

Figure 8: Significant difference in theta oscillation power (position F7) among AAT pre and Interval 4 only in active condition

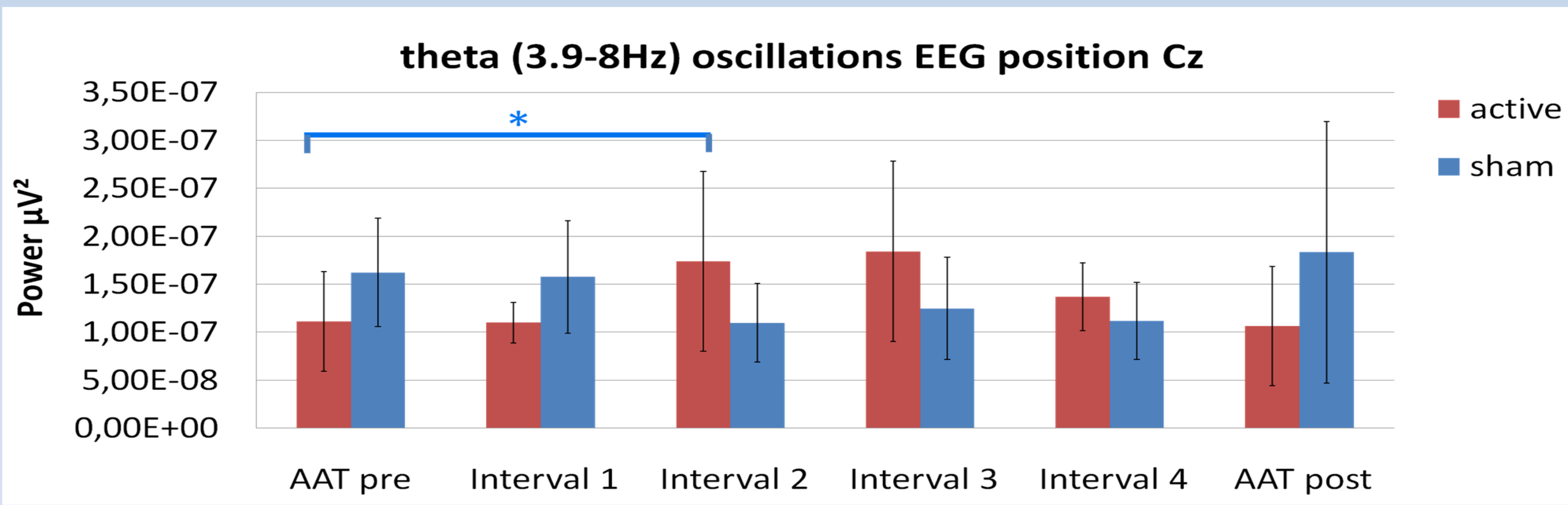

Figure 10: Significant difference in theta oscillation power (position Cz) among AAT pre and Interval 2 only in active condition

Discussion

Performance test results reveal that it is possible to elevate cognitive alertness of healthy subjects through anodal so- tDCS. Moreover, a power increase in theta at frontal as well as at central electrode sites was found, indicating that theta oscillations might mediate short term memory improvement. This is in line with previous results identifying theta as promoter for hippocampal encoding processes [Kirov et al., 2009].

Of specific interest is the fact that a slow oscillation power increase in central sites was observed but no effect in frontal sites. This is contradictory to the results from Kirov et al. (2009) and should therefore further elaborated.

For definite conclusions final data collection and analysis need to be completed, including evaluation of more EEG electrode sites and artifact removal procedures.

References:

Kirov, R., Weiss, C., Siebner, H. R., Born, J., and Marshall, L. 2009. Slow oscillation electrical brain stimulation during waking promotes EEG theta activity and memory encoding. *P. Natl. Acad. Sci. USA.*106, 36 (Sept. 2009), 15460-15465. DOI= http://www.pnas.org/cgi/doi/10.1073/pnas.0904438106.

Levy, R., and Goldman-Rakic, P. S. 2000. Segregation of working memory functions within the dorsolateral prefrontal cortex. *Exp. Brain. Res.*133 (May. 2000), 23-32. DOI= http://dx.doi.org/10.1007/s002210000397.