Modulation of Pain-Related Oscillations Using tACS

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Introduction

- Previous studies have highlighted that altered **theta** and **alpha oscillations** could be related to pain perception [1,2].
- **tACS**, provides new opportunities for understanding and manipulating these oscillatory activities [3,4].

Aim

- To assess whether there is a link between ongoing neural oscillations and pain perception.

Method

- 38 healthy participants were recruited (age: 28±8, 18 male)
- To induce pain perception, we used sustained and **periodic 0.2 Hz thermonociceptive** stimuli (temperature baseline and peak were set to 35°C and 50.5°C, respectively)
- **Focal tACS** (4×1 montage) was delivered using a Starstim tES-EEG.
- **M1** area of the contralateral dominant hand was stimulated.

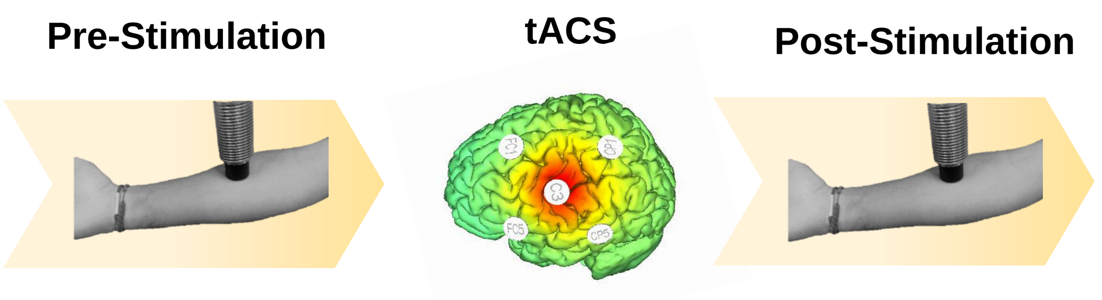

Figure 1. Thermal stimulation applied to the forearm with EEG measurements recorded to assess brain activity pre- and post-stimulation.

- The stimulation frequency: individual peak alpha frequency (PAF). **Sensorimotor PAF (SM-PAF)** was distinguished from visual PAF (VIS-PAF) and mixed sensorimotor and visual PAF (MIX-PAF).
- If the algorithm detected SM-PAF, it was chosen. If not, MIX-PAF, VIS-PAF, or 10 Hz were selected, respectively, based on their detection.
- A **sham** stimulation was used as a control condition.
- Behavioral measurements: warm detection threshold (**WDT**), heat pain threshold (**HPT**), perceived **painfulness** of periodic thermal stimuli (0-1), and subjective perceived **intensity** of stimuli (0-10).
- EEG analyses was performed using **frequency tagging (FT) on phase-locked response, theta (4-7Hz) and alpha (7-13Hz).**
- Linear Mixed Model (**LMM**) statistical test was used.

Result

Behavioral response

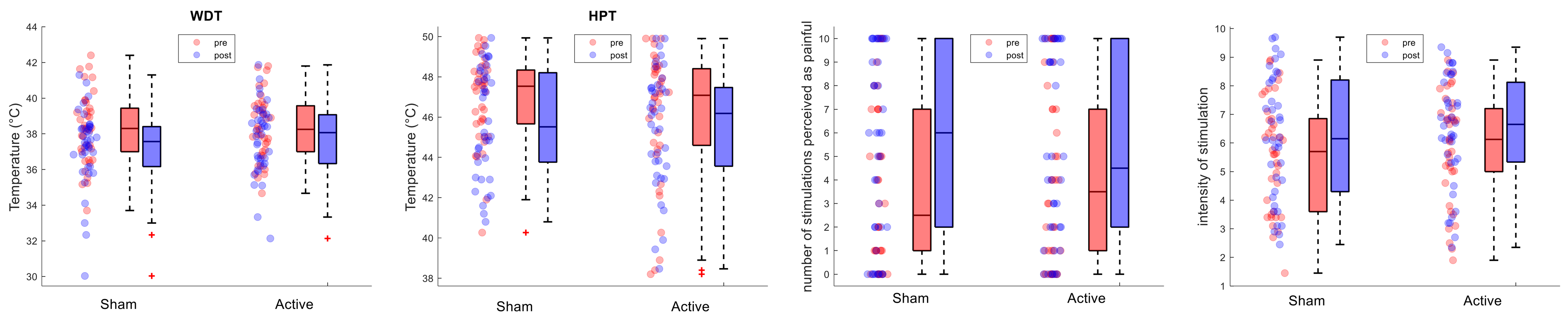

Figure 2: (a) WDT (b) HPT (c) painfulness rate (d) perceived intensity of stimulations . Significant time effect is detected ($p<0.01$) for painfulness and intensity rating.

Phase-locked response

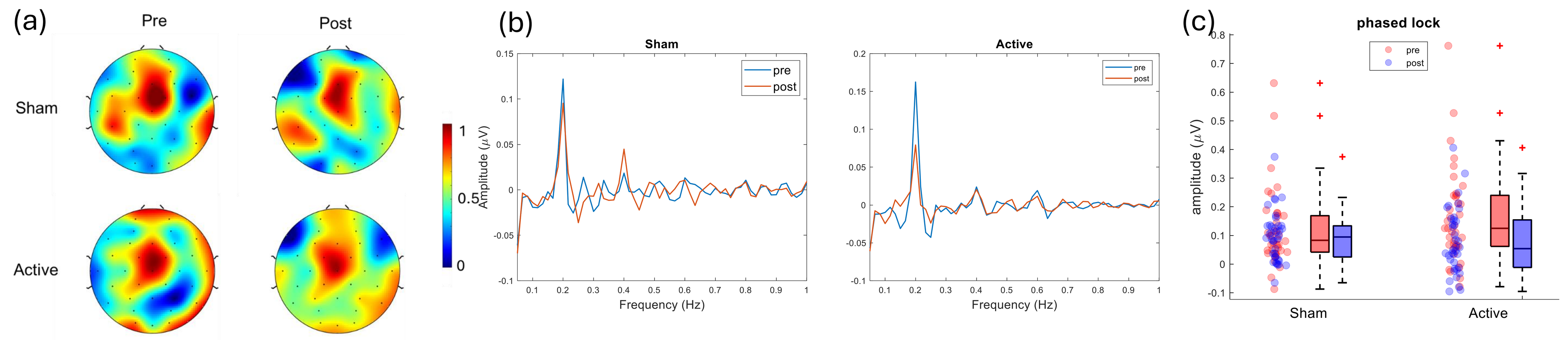

Figure 3 : (a) distribution **of significant 0.2Hz peaks**. (b) averaged frequency-tagged response at Fz; (c) peak amplitudes at 0.2 Hz at Fz. Significant time effect is detected ($p<0.01$).

Theta band response

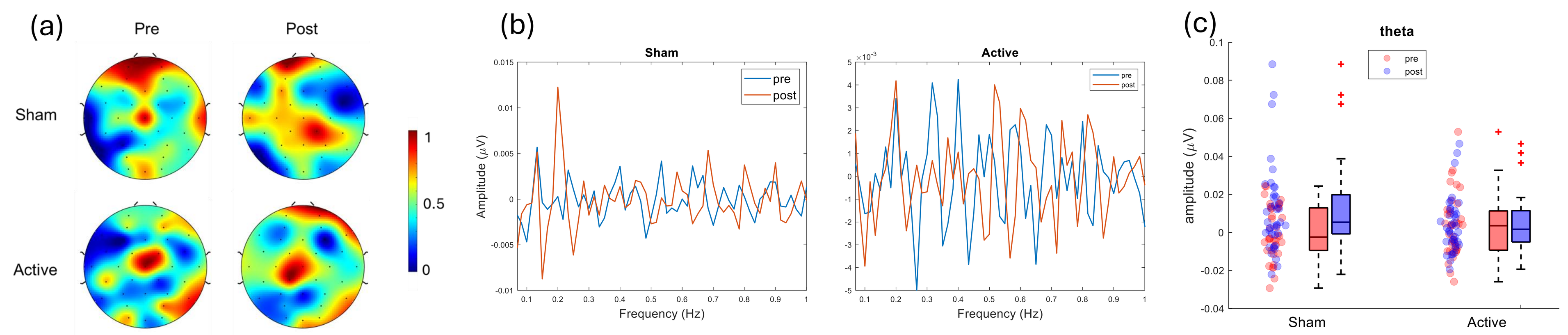

Figure 4: (a) distribution **of significant 0.2Hz peaks**. (b) averaged frequency-tagged response at **CP2**; (c) peak amplitudes at 0.2 Hz at **CP2**. Significant effect is detected for post sham **($p<0.05$)**.

Alpha band response

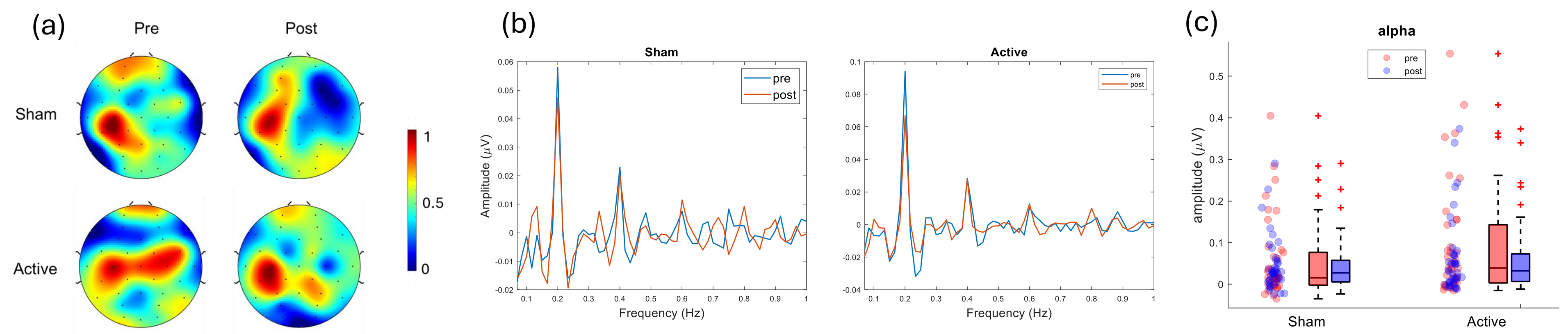

Figure 5: (a) distribution **of significant 0.2Hz peaks**. (b) averaged frequency-tagged response at **C3**; (c) peak amplitudes at 0.2 Hz at **C3**. Significant time effect is detected ($p<0.05$).

Peak Alpha Frequency Analysis

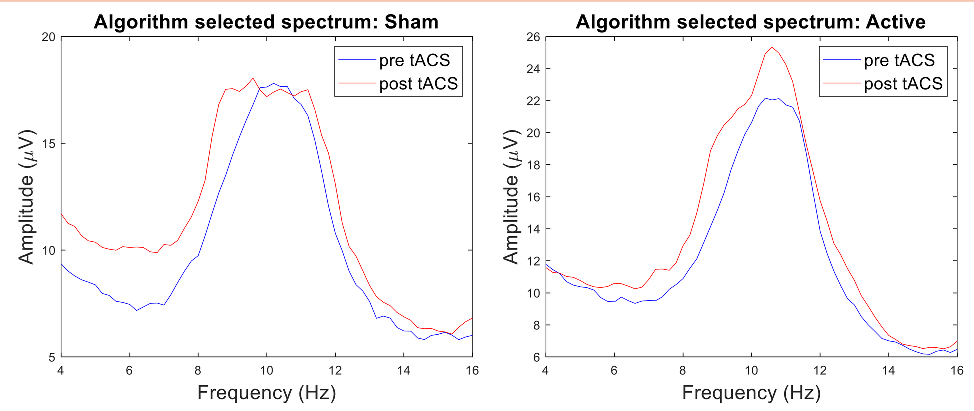

Figure 6: Averaged spectrum of selected alpha signals (SM, MIX, or VIS) for all conditions. Averaged PAF values: pre-sham: 10.02 Hz, post-sham: 9.98 Hz (decreased by 0.06 Hz, but N.S.); pre-active: 10.04 Hz, post-active: 10.04 Hz (**no change**).

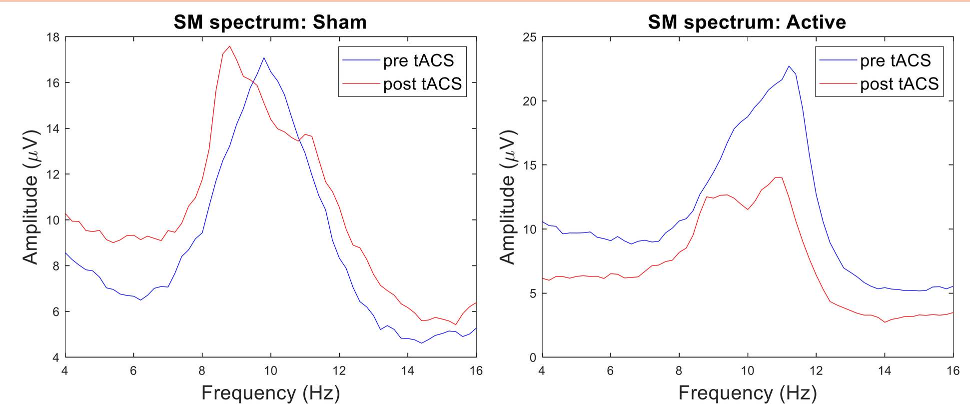

Figure 7: Averaged spectrum of Sensorimotor alpha signals (SM) for all conditions. Averaged PAF values: pre-sham: 10.01 Hz, post-sham: 9.95 Hz (decreased by 0.06 Hz, N.S.); pre-active: 9.99 Hz, post-active: 9.93 Hz (decreased by 0.06 Hz, N.S.).

Conclusion

- Although the same thermal stimulation was delivered pre- and post-tACS, we observed a significant increase ($p<0.01$) in pain perception and intensity ratings for both sham and active conditions. This increase correlated with decreased heat pain and warm detection thresholds, suggesting potential mild **sensitization** during the experiment.
- However, there was no significant effect of tACS on pain perception. Significant decreases in phase-locked response ($p<0.01$) and alpha FT response ($p<0.05$) were observed but were not significant for tACS conditions.
- A **significant increase in theta FT response in the posterior** scalp regions after sham and the higher trend of pain post-sham align with the preferential modulation of theta oscillations in the posterior insula during thermonociceptive stimuli [1].
- The decreased SM alpha spectrum amplitude may explain the reduced FT response and the lesser increase in pain perception post-active tACS. However, no significant results were found.
- The **average PAF remained constant with increased amplitude after active tACS**, as expected. The decrease in average PAF was not significant but the associated increase in pain for the sham condition align with previous literature on chronic pain patients [5].

Future works

- Exploratory analyses to identify more consistencies
- Considering changes in inter-regional **connectivities**.
- Exploring **theta-tACS** which has shown effectiveness in [6]

Acknowledgment

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Reference

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