Improving numerical methods for transcranial electrical stimulation - PKSTIM

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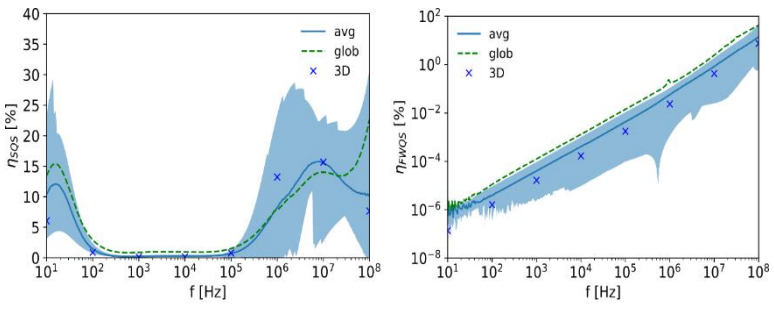
Context and objectives

- **Non-invasive brain stimulation** is a technology that holds promises for the symptomatic treatment of neurological disorders.
- **Transcranial alternating current stimulation** (tACS) has been reported to improve various cognitive functions, by targeting specific neuronal oscillations involved in the execution of those functions.
- Cognitive function impaired in **Parkinson's disease** (PD), right inferior frontal gyrus (rIFG) stimulation protocol was designed to target subject-specific oscillation frequency in the **beta band** (13-30 Hz).
- Here, we aimed at providing insights from a numerical modeling perspective to improve tACS protocols (frequency, EF delivery) and a better understanding of underlying mechanisms
- We also investigated the possibility of designing high-frequency stimulation

Electric field modeling approximations

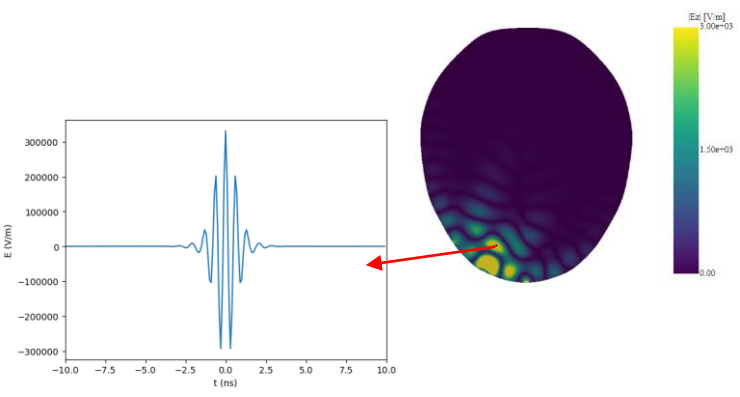
Study about approximations made to numerically predict the electric field in the brain.



- Limit on the quasi-static approximation (~1,4 MHz) and importance of considering dielectric properties.

Investigating a new way for neurostimulation

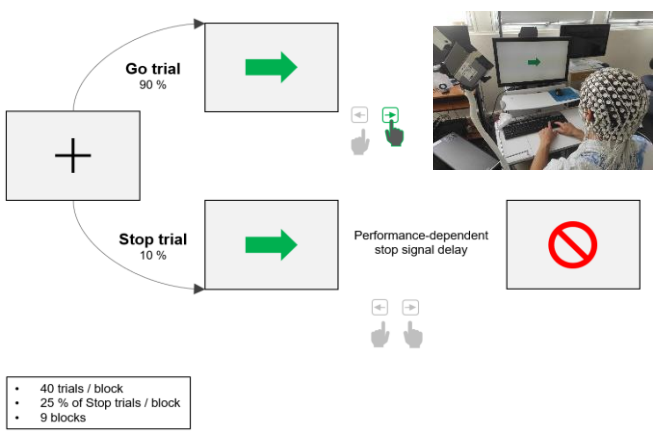
Using focused radio frequency electromagnetic wave increases temperature and induce neuromodulatory effects while limiting SAR.



Clinical trial

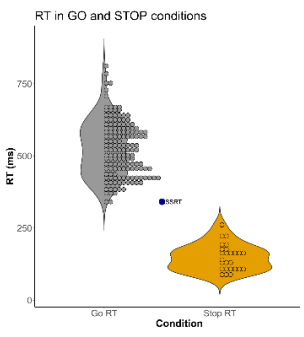
Can personalized tACS relieve inhibition deficits in patients with Parkinson's Disease (PD)?

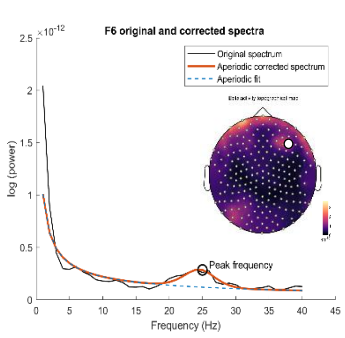
- Inhibition evaluation (Stop Task) with concomitant High Density EEG recordings:



- 40 trials / block
- 25 % of Stop trials / block
- 9 blocks

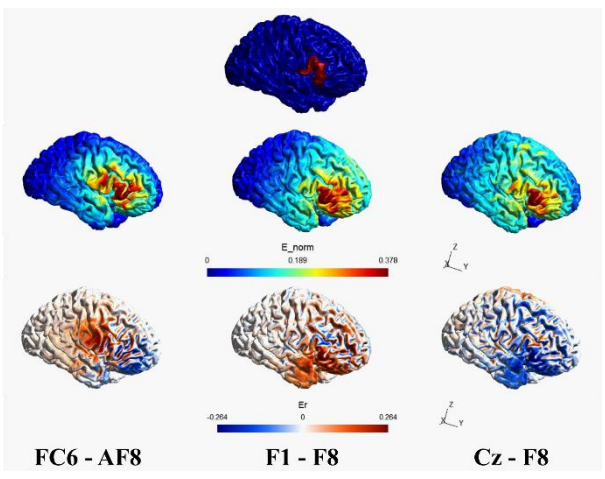
- Stop Signal Reaction Time inferred from behavioral results.
- tACS target evaluated from task-related EEF results.





→ In that pilot subject, frequency of tACS would be set to 25 Hz.

- Need to define a montage for stimulating the target using tACS: *a priori* optimization using numerical head models

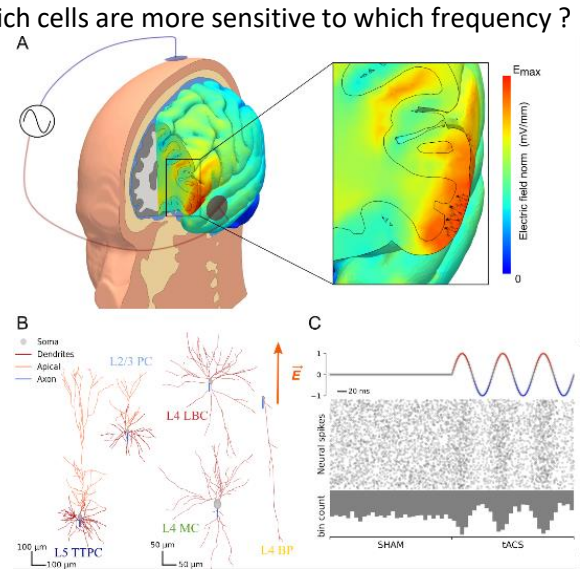


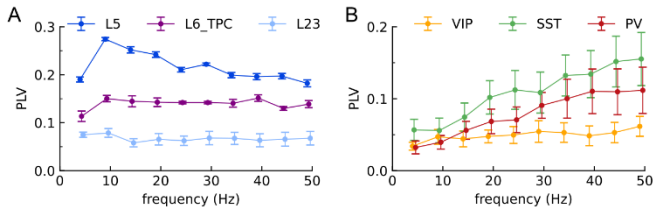
- Manual – homemade coded – SimNIBS optimizations for stimulating the **rIFG,** 8 subjects → **F8-Cz** montage

Study now started with Parkinsonian and control patients.

Modeling neural activity during tACS

Modeling tACS on biophysically and morphologically realistic neurons: Could we improve our understanding of tACS effects on spike timing and oscillation phase? Which cells are more sensitive to which frequency ?





- Inhibitory neurons entrained at higher frequencies
- excitatory more at endogenous frequency

Publication list

- Gaugain, G. *et al.* (2021) 'Modeling accuracy of transcranial current stimumation: Static and quasi-static approximations errors', in *Proc. BioEM 2021*. *BioEM 2021*, Ghent.
- Gaugain, G., Modolo, J., *et al.* (2022) 'Effect of permittivity on temporal interference modeling', in *Proc. BioEM 2022*. *BioEM 2022*, Nagoya
- Gaugain G, Quéguiner L, Bikson M, Sauleau R, Zhadobov M, Modolo J, et al. Quasi-static approximation error of electric field analysis for transcranial current stimulation. J Neural Eng 2023. https://doi.org/10.1088/1741-2552/acb14d.
- Gaugain, G., Modolo, J. and Nikolayev, D. (2022) 'Temporal interference modeling error using purely conductive medium appoximation', in *2022 44th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)* Glasgow: IEEE.
- Gaugain, G., Al Harrach M., Yochum M., Modolo J., and Nikolayev D., Phase entrainment of cortical cell types during tACS: a modeling study. *In preparation for submission*

Conclusion & future prospects

- We explored how EF is modeled in tACS and the limit of common approximations for calculations
- Exploring the response of neural models, we identified which cells preferentially respond to which stimulation frequency
- Investigation of new neurostimulation frequencies and devices