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► To cite this version:

Gaia Zin, Guy Nagels, Jeroen van Schependom, Thanos Manos. Combining structural and functional connectomes to estimate changes in excitatory and inhibitory activity in people with Multiple Sclerosis. International Multiple Sclerosis Cognition Society, Sep 2024, Bern, Switzerland. hal-04690909

HAL Id: hal-04690909

<https://hal.science/hal-04690909v1>

Submitted on 6 Sep 2024

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Combining structural and functional connectomes to estimate changes in excitatory and inhibitory activity in people with Multiple Sclerosis.

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Background

- Clinical radiological paradox:
The number and volume of Multiple Sclerosis (MS) lesions is not a sufficient sole indicator of MS severity [1].
- Neurocomputational models have been employed to study the disorder but they mostly fail to reproduce negative correlations present in empirical data.
- The brain operates at a critical state. A disruption of the Excitation Inhibition Balance (EIB) is linked to neurological disorders.

Objective

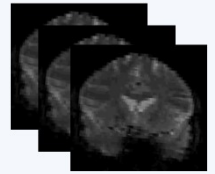
Model link between functional (FC) and structural (SC) connectivity and see if it allows to measure the change in EIB in MS.

Data

13 HC female
25 MS female
age $\mu \pm \sigma$:
44 \pm 12 and 48 \pm 11



Diffusion Weighted Image (DWI)



Resting state fMRI (rsfMRI)

Method

Ising model (statistical mechanics)

⇒ generate a **signed structural connectivity** from DWI and rsfMRI.

- Binarize BOLD time series for ROI to a series of states of +1 or -1.
- Maximise the pseudolikelihood estimation of the new structural \mathbf{J} , given the probability of observing state $s_i(t)$ at the i th ROI, given all the other states $s_{-i}(t)$.

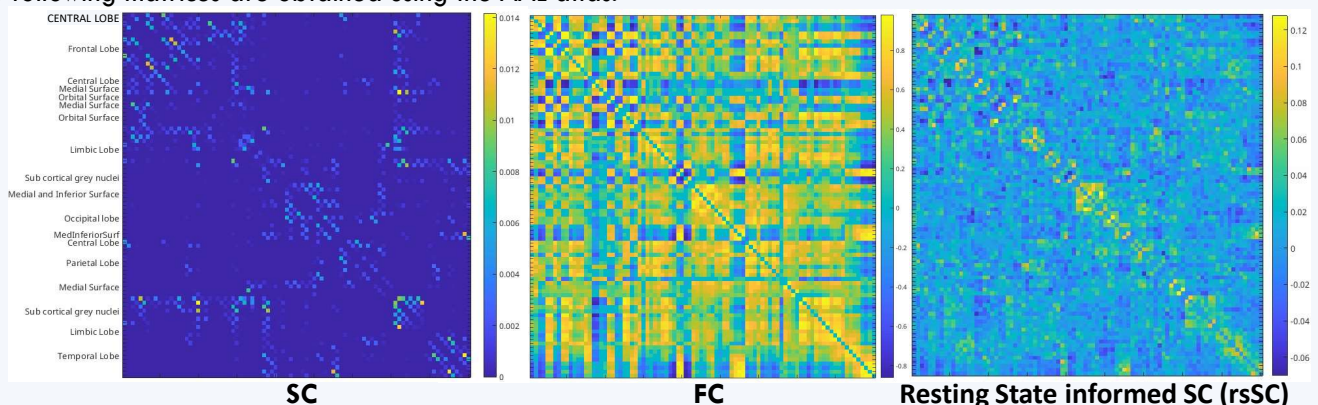
$$\mathcal{L}_{\text{pseudo}}(\mathbf{J}, \beta) = \prod_{t=1}^{t_{\max}} \prod_{i=1}^k \Pr(s_i(t) | \mathbf{J}, \beta, s_{-i}(t))$$

The sign of the computed structural connectivity might provide a link with EIB [2,3].

Combining functional and structural connectivity may provide a window on the Excitation Inhibition Balance in Multiple Sclerosis

Preliminary Results

The following matrices are obtained using the AAL atlas.



Future directions

- Study how the ratio of positive and negative entries in the rsSC changes in HC and people with MS (also with different atlas).
- Use rsSC as input for neurocomputational models.

[1] Barkhof, F. "The clinico-radiological paradox in multiple sclerosis revisited." *Current opinion in neurology* 15.3 (2002): 239-245.
[2] Fortel, I. et al. "Brain dynamics through the lens of statistical mechanics by unifying structure and function." *Medical Image Computing and Computer Assisted Intervention—MICCAI 2019: 22nd International Conference, Shenzhen, China, October 13–17, 2019, Proceedings, Part V 22*. Springer International Publishing, 2019.
[3] Manos, T., et al. "Enhanced simulations of whole-brain dynamics using hybrid resting-state structural connectomes." *Frontiers in computational neuroscience* 17 (2023): 1295395.