Towards data-driven brain stimulation target discovery using single-subject whole brain models

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Introduction

Disorders of Consciousness (DoC) are difficult to treat due to (i) our limited knowledge on the neural correlates of consciousness and (ii) the heterogeneity of their causes. Current treatments have been proved to be limited in their effectiveness. In the recent years, **brain stimulation** has been proposed as a potential treatment with great potential. However, finding suitable targets for said stimulation is difficult. Here we propose a **model-based approach to find stimulation targets**.

Dataset

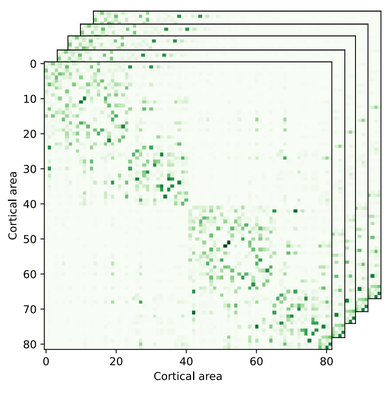
Macaca mulatta
fMRI data

- Anesthesia without stimulation
- Anesthesia + DBS stimulation of Ventrolateral nuclei of the Thalamus (VL) (3 Volts and 5 Volts)
- Anesthesia + DBS stimulation of Central Thalamus (CT) (3 Volts and 5 Volts)

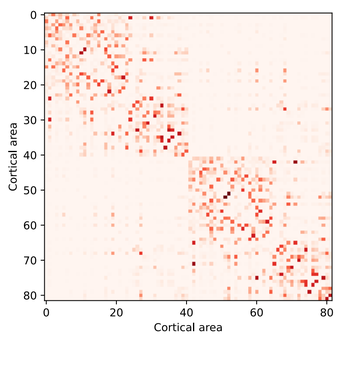
5V CT stimulation restored signatures of consciousness *(Tasserie et al. 2022)*

Methods

Functional data



Structural data



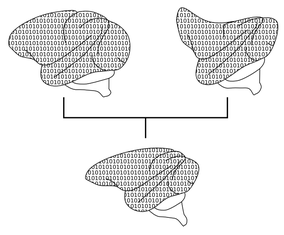
Whole Brain Model

Coupled Stuart-Landau Oscillators

$$\frac{dx_j}{dt} = \left(a_j + x_j^2 + y_j^2\right) x_j - \omega_j y_j + G \sum_{i \neq j} C_{ij}(x_i - x_j) + \beta \eta_j$$

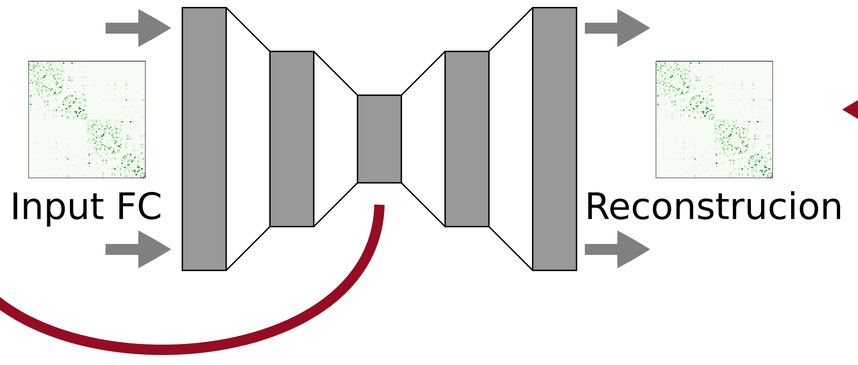
$$\frac{dy_j}{dt} = \left(a_j + x_j^2 + y_j^2\right) y_j + \omega_j x_j + G \sum_{i \neq j} C_{ij}(y_i - y_j) + \beta \eta_j$$

Model fitting
via Genetic Algorithm

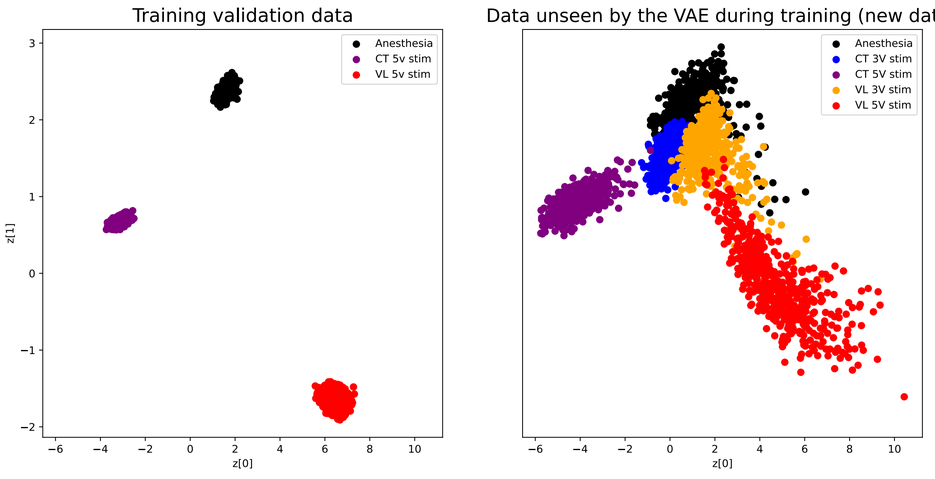


Dimensionality reduction and clustering due to differences in Functional Connectivity (FC) via Variational Autoencoder (VAE)

Training with simulated data from models fitted for anesthesia, VL and CT stimulations with 5 Volts



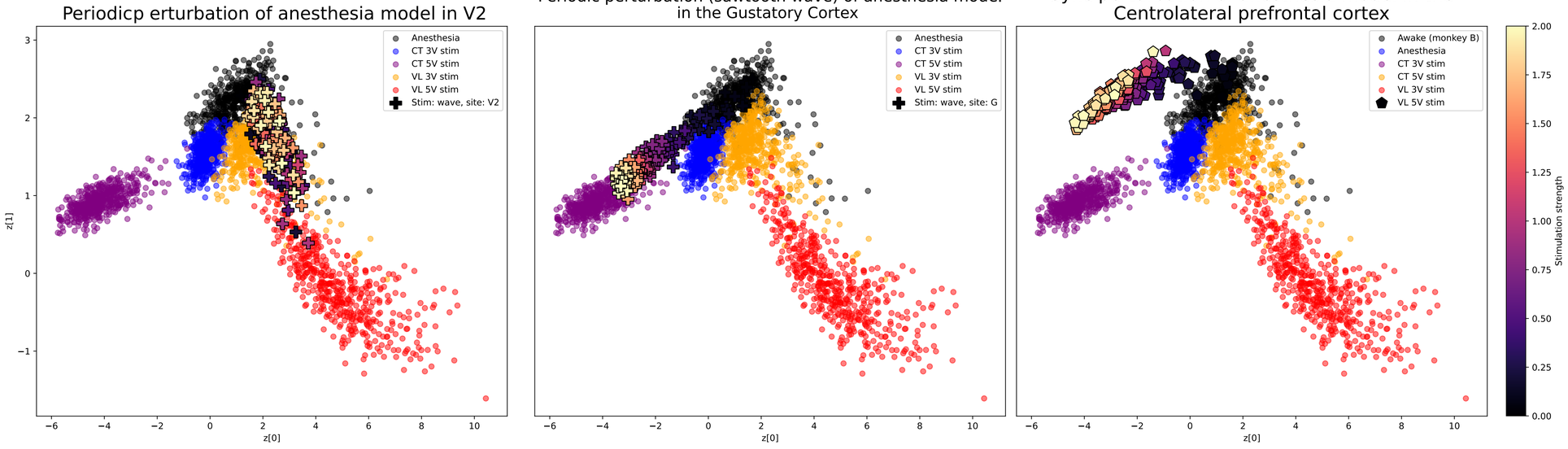
Latent Space embedding of F-Cs



By perturbing the model fitted to the anesthesia condition we can see how the dynamic change in the latent space and study brain transitions to other states

Perturbing by adding a periodic forcing term or by changing the bifurcation parameter (a_j) of the starting model (anesthesia)

Results



[LEFT] We are able to **reproduce the 3V VL stimulation** by perturbing both V2 areas, which were the only ones reported as during 3V VL stimulation

[MIDDLE] We **find novel ways of obtaining the brain dynamics** from the CT 5V stimulation, such as stimulating the gustatory cortices (which would be an interesting experiment)

[RIGHT] Some perturbations move the system to 'uncharted' territory. Not shown is how, that space in latent space, is actually occupied by the dynamics of models fitted on **awake monkey** data

References

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Monkey photo: Rhesus monkey in the DPZ, at the German Primate Institute Photo: Anton Säckl

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