The attractor states of the functional brain connectome

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Tuesday 27th June, 2023

Abstract

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Keywords

Highglights:

- continous "activity flow" across brain regions
- considerung the functional brain connectome as the weights of

1 Introduction

Measuring localized brain activity, e.g. with functional magnetic resonsnace imaging (fMRI) have provided a wealth of insights into the neural correlates of several behavioral/psychological phenotypes and clinical conditions.

However, functional connectivity has been shown to be dynamic; it fluctuates spontaneously over time in a globally coordinated manner. Dynamic functional connectivity has quasi periodic properties (ref), with a limited number of recurring states ("brain states") (Gutierrez-Barragan et al. [2019]); i.e. sporadic intervals during which information can be efficiently exchanged between a characteristic subset of brain regions (Hutchison et al. [2013], Liu and Duyn [2013], Zalesky et al. [2014]). Brain state dynamics can be assessed with multiple techniques, including independent component analysis (ref), co-activation patterns (Liu and Duyn [2013]), and there is accumulating evidence for the neurobiological relevance of these dynamics, with promising perspectives for facilitating the clinical translation of functional neuroimaging techniques by improving brain based biomarkers (Lee et al. [2021]).

However, progress is limited by gaps in the mechanistic understanding of how brain activity and functional connectivity dynamically shape each other and how this process leads to the emergence and organization of brain states (ref).

Here we propose a novel model-based framework that - with minimal and reasonable assumptions about the "activity flow" (ref: Cole-papers) between two, functionally connected regions - considers the stationary functional brain network as an already-trained artificial neural network. In the proposed framework, the topology of the stationary brain connectome defines a cost (energy) for any arbitrary brain activation patterns and a trajectory towards one of the finite number of stable patterns that minimize this cost (so-called attractor states).

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- noise

Here we propose these attractors states as robust and neurobiologically relevant characteristics of the functional brain connectome, with a wide variety of potential applications.

We demonstrate that the proposed attractor states highly resemble to the dynamic brain states commonly observed by dynamic functional connectivity methods (e.g. CAP-analyses (ref)) and provide a proof-of-concept for the biomedical validity of our framework, by showing that the average brain activations corresponding to the attractor states during resting sate display manifold significant associations to cognition.

Due to the known noise-tolerance of the applied eANN-s, the proposed approach can be expected to be highly robust/reliable/replicable, which we demonstrate with independent datasets (total n=xxx).

List all the aims: hierarchy, generalizability etc

2 Results

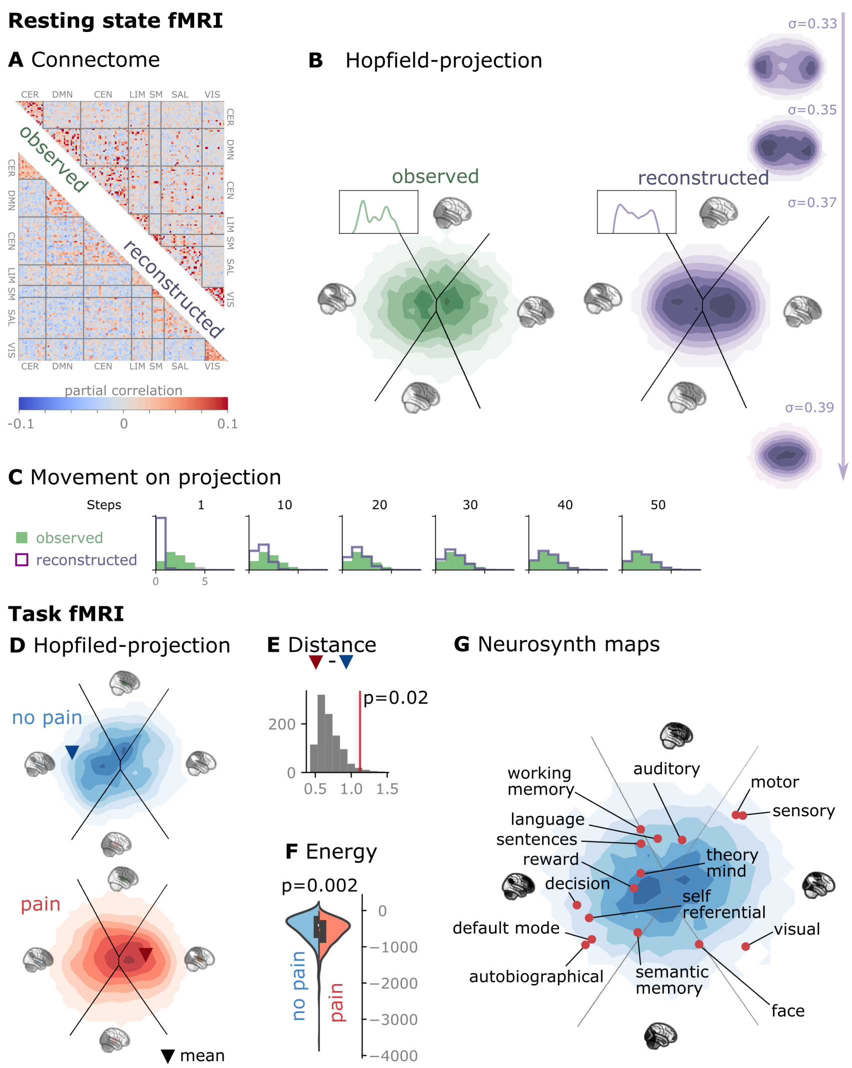

Figure 1: Empirical Hopfield-networks reconstruct real brain activity.

Here I refer to Figure 1.

3 Discussion

4 Methods

Todo

Todo

References

Daniel Gutierrez-Barragan, M. Albert Basson, Stefano Panzeri, and Alessandro Gozzi. Infraslow state fluctuations govern spontaneous fMRI network dynamics. *Current Biology*, 29(14):2295–2306.e5, jul 2019. doi:10.1016/j.cub.2019.06.017. URL https://doi.org/10.1016%2Fj.cub.2019.06.017.

R. Matthew Hutchison, Thilo Womelsdorf, Elena A. Allen, Peter A. Bandettini, Vince D. Calhoun, Maurizio Corbetta, Stefania Della Penna, Jeff H. Duyn, Gary H. Glover, Javier Gonzalez-Castillo, Daniel A. Handwerker, Shella Keilholz, Vesa Kiviniemi, David A. Leopold, Francesco de Pasquale, Olaf Sporns, Martin Walter, and Catie Chang. Dynamic functional connectivity: Promise, issues, and interpretations. *NeuroImage*, 80:360–378, oct 2013. doi:10.1016/j.neuroimage.2013.05.079. URL https://doi.org/10.1016%2Fj.neuroimage.2013.05.079.

Xiao Liu and Jeff H. Duyn. Time-varying functional network information extracted from brief instances of spontaneous brain activity. *Proceedings of the National Academy of Sciences*, 110(11):4392–4397, feb 2013. doi:10.1073/pnas.1216856110. URL https://doi.org/10.1073%2Fpnas.1216856110.

Andrew Zalesky, Alex Fornito, Luca Cocchi, Leonardo L. Gollo, and Michael Breakspear. Time-resolved resting-state brain networks. *Proceedings of the National Academy of Sciences*, 111(28):10341–10346, jun 2014. doi:10.1073/pnas.1400181111. URL https://doi.org/10.1073%2Fpnas.1400181111.

Jae-Joong Lee, Hong Ji Kim, Marta Čeko, Bo yong Park, Soo Ahn Lee, Hyunjin Park, Mathieu Roy, Seong-Gi Kim, Tor D. Wager, and Choong-Wan Woo. A neuroimaging biomarker for sustained experimental and clinical pain. *Nature Medicine*, 27(1):174–182, jan 2021. doi:10.1038/s41591-020-1142-7. URL https://doi.org/10.1038%2Fs41591-020-1142-7.