Information dynamics in a model of EEG brain rhythms

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In recent years, several new information theory tools were developed to study complex systems. One of them is information dynamics (ID), which studies how a complex system locally stores, transfers, and modifies information. Another tool is Partial Information Decomposition (PID), which analyses the information between random variables by decomposing it into three types of information "atoms": unique, redundant, and synergistic, each of them capturing different fundamental relations between variables. A recently developed framework called Integrated Information decomposition (Φ-ID)[4] is constructed using ideas from Integrated Information Theory (IIT) [3] and both ID and PID, providing a more general framework for exploring information dynamics in complex systems. In this study, we apply Φ-ID to explore the behavior of a neuronal network with a rich and well-known phase diagram [5] with different emerging dynamical phases associated with familiar brain waves observed in EEG recordings (see 1). Our analysis shows that: i) the system has the maximum integrated information Φ^R in a region where excitatory neurons exhibit the maximum variance, in a transition between intermediate neuronal activity with clear dominant rhythms β and high activity where γ oscillations dominates (see 2); ii) local information transfer appears to be maximum in a metastable region where δ and β waves dominates (not shown); iii) at short time scales, the inhibitory population has maximum information storage close to a first-order transition (not shown). In conclusion, in our model, the emergence of EEG-like rhythms at the collective level encompasses a rich information dynamics. This simple model can help to better understand the relationship between different brain rhythms and local information dynamics.

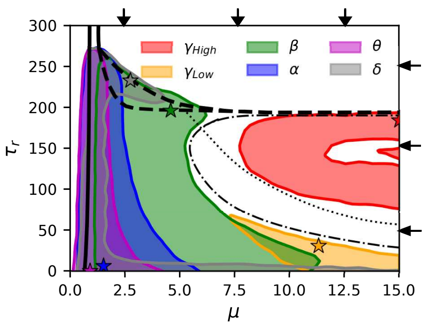

Fig. 1. **Phase diagram of rhythms in the model**. Rhythms observed in the excitatory population across the phase diagram by power spectrum analysis of average membrane potential. Each color shows a specific band of brain rhythms. The colored starts indicate the maximum of maximums for each rhythm.

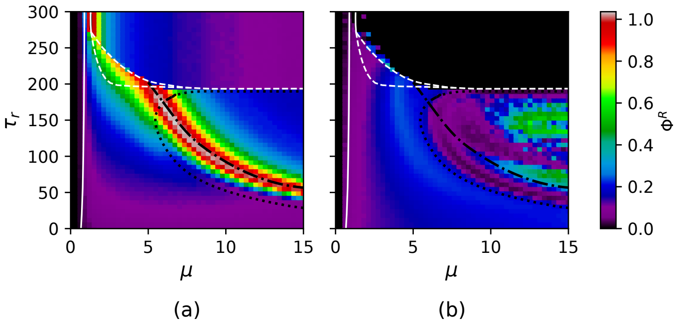

Fig. 2. **Integrated information ϕ^R across phase diagram**. The solid(dashed) white line describes a second-order(first-order) phase transiton. The dotted (dash-dotted) white line indicates the maximum variance in the states of the I (E) neurons. (a) Φ^R in the excitatory group of 12E. (b) Φ^R in the inhibitory group of 9I.

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