BMC Neuroscience

BioMed Central

Poster presentation

Inter-cortical time delays shape the brain in dynamical networks during rest

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from Eighteenth Annual Computational Neuroscience Meeting: CNS*2009
Berlin, Germany. 18–23 July 2009

Published: 13 July 2009

BMC Neuroscience 2009, **10**(Suppl 1):P70 doi:10.1186/1471-2202-10-S1-P70

This abstract is available from: http://www.biomedcentral.com/1471-2202/10/S1/P70

Introduction

A growing body of neuroimaging research has documented that, in the absence of an explicit task, the brain shows temporally coherent activity [1]. This so-called "resting state" activity or, more explicitly, the default-mode network has been associated with day dreaming, free association, stream of consciousness or inner rehearsal in humans, but similar patterns have also been found under anaesthesia and in monkeys [2]. This resting state is characterized by slow fluctuations (<0.1 Hz), and is topographically organized in anticorrelated distributed cortical networks, which are the same networks that are also typically seen during attentional tasks [3]. The origin of such organization in different networks remains unclear. It has been speculated that the origin of such networks is mainly due to the structural topology, i.e. the cortical connectivity. Nevertheless, dynamics should play a crucial role in shaping the partition of such networks, in particular because the transmission of information between cortical areas is not instantaneous, due to axonal conduction and synaptic transmission times. Using a realistic connectivity matrix for the Macaque's brain such as the CocoMac [4], we demonstrate that time delays structure the brain in dynamical networks during rest which are different from the ones resulting from a pure connectivity analysis.

Methods

In the time-independent cases, topological scales are revealed through synchronization [5] but the extension to time-delayed networks has not been fully analyzed. Considering that resting state patterns arise from a phenomenon associated with synchronization, we extend the theory of [5] to time-delayed networks. According to this method, we consider the brain as a network of coupled phase-oscillators with their temporal dynamics given by the Kuramoto model, in our case allowing time-delayed interactions [6]. The nodes oscillate at a mean intrinsic frequency of 40 Hz to simulate the local fast dynamics of brain regions.

Results

In the particular case of infinite speed, i.e., without time delay, the first modules to synchronize are the ones given by the topological connectivity structure. When we introduce a global delay the synchronization of topological communities is disrupted and other synchronization patterns appear. For specific delays, the network finds an equilibrium point distant from full synchronization. When we use the Macaque's brain structure and the corresponding realistic time delays distribution, we show under resting state conditions the emergence of clusters of 40 Hz oscillators that are synchronized within each cluster and anti-correlated at <0.1 Hz across the clusters in line with a wide range of recent experimental observations.

Acknowledgements

This work was supported by the *Fundação para a Ciência e Tecnologia*, POCI 2010, FSE SFRH/BD/36730/2007, and European Community's Seventh Framework Programme (FP7/2007-2013), Grant Agreement n° HEALTH-F2-2008-200728.

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