Using transfer entropy to unveil the effective connectivity for MEG measurements: an application to a Simon task.

Raul Vicente$^{1,2}$, Michael Wibral$^3$, Jochen Triesch$^2$, and Gordon Pipa$^{1,2,4}$

$^1$Department of Neurophysiology, Max-Planck Institute for Brain Research, Frankfurt am Main, Germany, $^2$Frankfurt Institute for Advanced Studies (FIAS), Frankfurt am Main, Germany, $^3$Brain Imaging Center, Frankfurt am Main, Germany, $^4$Massachusetts Institute of Technology (MIT) and Massachusetts General Hospital (MGH), USA.

The functional connectivity of the brain describes the network of statistically correlated activities of different brain areas. However, as it is well known correlation does not imply causality and most of synchronization measures are not able to distinguish context-dependent causal interactions among remote brain areas, i.e. to determine the so-called effective connectivity [1]. This type of effective or causal brain networks is a fundamental step in unveiling the neural circuitry of brain areas and its directed interactions involved in the processing of information.

In this work we make use of the transfer entropy concept to establish the effective connectivity of healthy human brains under a simple Simon task from MEG measurements with a view to test the validity of this approach in neuroimaging techniques. The formalism of transfer entropy, based on information theory, has recently been proposed as a rigorous quantification of the information flow among several systems in interaction and it is the natural generalization of the well-known mutual information [2]. In the experiment the subjects are presented with an "L" or "R" letter in either the left or the right side of a screen and instructed to press a left-side key in response to the "L" letter and the right-side key in response to the "R" letter, independently of the spatial location of the stimulus. The data were collected with a whole-head 275 channels CTF-MEG scanner at a temporal resolution of 1.2 kHz.

After appropriate preprocessing and artifact rejection of the MEG data, the transfer entropy between all possible pairs of channels was computed with a Kozachenko-Leonenko estimator while the statistical significance of the causal interactions was determined by a non-parametric permutation test. The flow of information revealed that different neuronal circuits (including long-range causal influences as interhemispheric temporal lobe interactions) are recruited for the four different experimental conditions ("L" letter on the left side, "R" letter on the right side, "L" letter on the right side, and "R" letter on the left side) during the processing of the visual stimulus and production of the appropriate motor response, in accordance to the physiologically expected predictions. The effective networks of Simon versus non-Simon effect conditions (the first two conditions versus the last two) are also compared and analyzed in basis to advance in the use of effective connectivity as a tool to better understand and classify different cognitive processes.

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References