

Removing instantaneous correlations between BOLD fMRI time series to improve connectivity estimation

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Introduction

The investigation of brain connectivity through spectral Granger causality indices is a widely adopted approach in the neuroimaging field, and it has been successfully applied, among other techniques, also on BOLD fMRI data. The evaluation of such connectivity measures relies on the estimation of the coefficients of a multivariate autoregressive model (MVAR). In the original formulation, though, the estimated model only includes lagged terms, therefore omitting the potential contribution of instantaneous correlations between the analyzed time series. This issue has been recently addressed by Faes and Nollo, who proposed an extended MVAR (eMVAR) framework, allowing to take into account the zero-lag interactions, and applied it on cardiovascular variability series and multichannel EEG recordings¹.

Purpose

The aim of the present study is to investigate whether removing the instantaneous correlations, considered as noise since not descriptive of pure causality in classic MVAR models formulation, improves the performance of spectral Granger causality estimation on BOLD fMRI data.

Methods

In this study, we evaluated fMRI data from an auditory paradigm², freely downloadable at http://www.fil.ion.ucl.ac.uk/spm/data/dcm_bms/. BOLD time series from 12 subjects were extracted from three regions of interest (ROIs): the posterior and anterior superior temporal sulcus (pSTS and aSTS, respectively) and pars orbitalis (POrb) of the inferior frontal gyrus. We applied eMVAR methods in order to compute both strictly causal and extended Partial Directed Coherence (PDC) and the resulting networks were compared with the results obtained through Dynamical Causal Modeling (DCM)², which identified pSTS as the driving node.

Results

Statistical analysis on the two sets of PDC indices revealed a significant increase in the connection strengths originating from pSTS in the extended model with respect to the strictly causal one (Fig. 1). Furthermore, median PDC values across subjects allow to identify pSTS as the driving node in the extended model, but not in the strictly causal model (Fig. 2), despite no significant difference was found between pSTS outgoing and incoming connections for both analyzed networks.

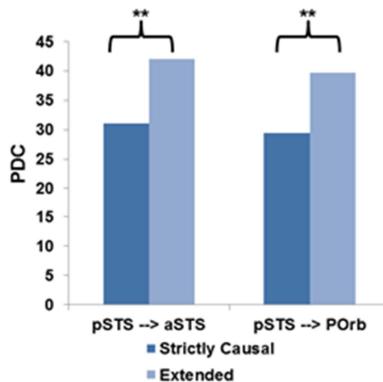


Figure 1 – Significantly (** = $p < 0.001$) increased connection strengths originating from pSTS in the extended model with respect to the strictly causal one.

Discussion

In this work, we addressed the removal of instantaneous correlations when estimating spectral Granger connectivity indices on BOLD data. Our results showed that adopting an extended model, that is, taking into account the zero-lag interactions and being able to remove them from the estimated causality indices, allows to achieve a better description of the network underlying the data.

We expect this approach to be useful both to improve the outcome of connectivity analysis and to investigate the potential physiological meaning of the instantaneous correlations themselves.

References

1. Faes L, Nollo G. Extended causal modeling to assess partial directed coherence in multiple time series with significant instantaneous interactions. *Biol Cybern* 2010;103(5):387-400.
2. Leff AP, Schofield TM, Stephan KE, Crinion JT, Friston KJ, Price CJ. The cortical dynamics of intelligible speech. *The Journal of Neuroscience* 2008;28(49):13209-15.

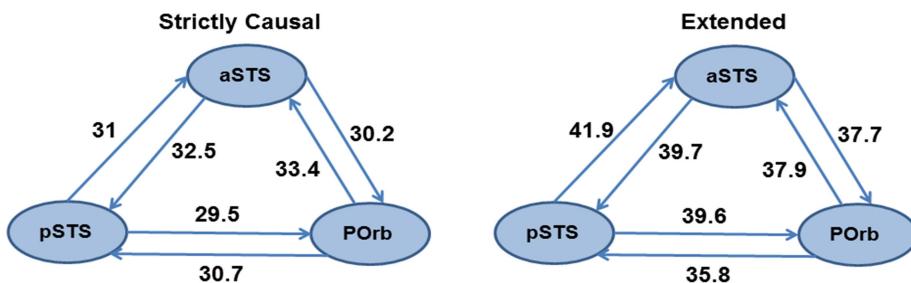


Figure 2 – Median PDC values across 12 subjects for both the strictly causal and the extended model. The driving role of pSTS node is revealed only when zero-lag correlations are removed.