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Inferring Higher-Order Hidden drivers from fMRI Data

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joint work with Zsigmond Benkő[1], Marcell Stippinger[1], Asadur Chowdury[2], David R. Rosenberg[2], Vaibhav A. Diwadkar[2]

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Traditional approaches to analyzing interactions between brain areas have primarily focused on networks built from pairwise relationships between measured activities. These include functional connectivity, typically quantified using correlation, and causality analyses, which aim to infer directional couplings between regions of interest. Only a few studies have attempted to infer the emergence of higher-order interactions between brain areas using multivariate extensions of entropy-based measures, such as Mutual Information, Total Correlation, Dual Total Correlation, or topological invariants. While these measures capture important aspects of information processing in the brain, some of their mathematical properties – such as the potential negativity of higher-order Mutual Information – limit their interpretability.

Here, we introduce a novel method to infer the dimensionality of higher-order hidden drivers based on multiple time series from dynamical systems. We prove the non-negativity of the interaction dimension analytically and validate our inference algorithm on simulated networks of dynamical systems. We then apply the method to fMRI time series data to investigate the existence and complexity of hidden common drivers among eight brain regions associated with visuomotor responding and working memory tasks. We find evidence of significant task-specific differences in higher-order driver structures, both in the involvement of specific groups of brain areas and in the typical order of the significant drivers.

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