Directed information structure in inter-regional cortical interactions in a visuomotor tracking task

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Distributed computation in the brain is a complex process, involving interactions between many regions in order to achieve a particular task. We present an analysis of functional Magnetic Resonance Imaging (fMRI) measurements of brain activity in 16 localized regions recorded while eight subjects (who gave informed written consent) control a mouse with their right hand to track a moving target on a computer screen. We examine the underlying interaction structure between region pairs, and the changes in that structure as a function of the difficulty of the tracking task. Our approach is distinguished in using asymmetric, multivariate, information-theoretical analysis, which captures not only *non-linear* relationships, but also *collective interactions* arising from groups of up to seven voxels in each region, and the *direction* of these relationships.

The statistical significance of the average transfer entropy [1,2] (a *directed* measure of information transfer) yields a distinct 3-tier directed interaction structure that underlies all task difficulties (see Fig. 1a). Importantly, this structure connects movement planning to visual and motor control regions. Random-effects statistical parametric maps (SPM) analysis is then used to determine which pairs of regions have: a. more in common (using the mutual information), or b. a more pronounced directional relationship (using the transfer entropy) as the task difficulty increases. Most significantly (see Fig. 1b), we identify an increased coupling between regions involved in movement planning (left SMA and left PMd) and execution (right cerebellum for right hand and right SC for eye movements) with task difficulty. It is likely these methods and extensions to them can be used to identify inter-regional structural changes due to other tasks and coherent information transfer structures in the cortex [3].
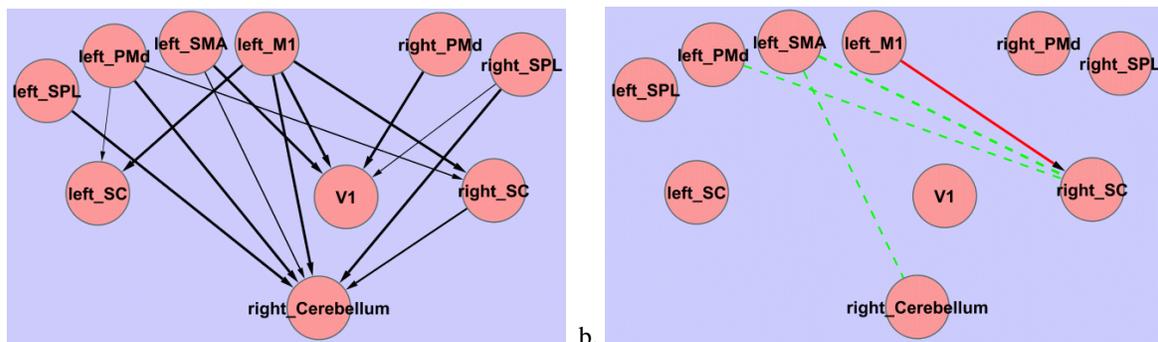

Fig 1. a. Directed relationships between selected regions, and b. the changes in the relationships (dashed green line = more in common, directed red line = a less directional relationship) as task difficulty increases.

References
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