A Method for Making Group Inferences Using Independent Component Analysis of Functional MRI Data: Exploring the Visual System

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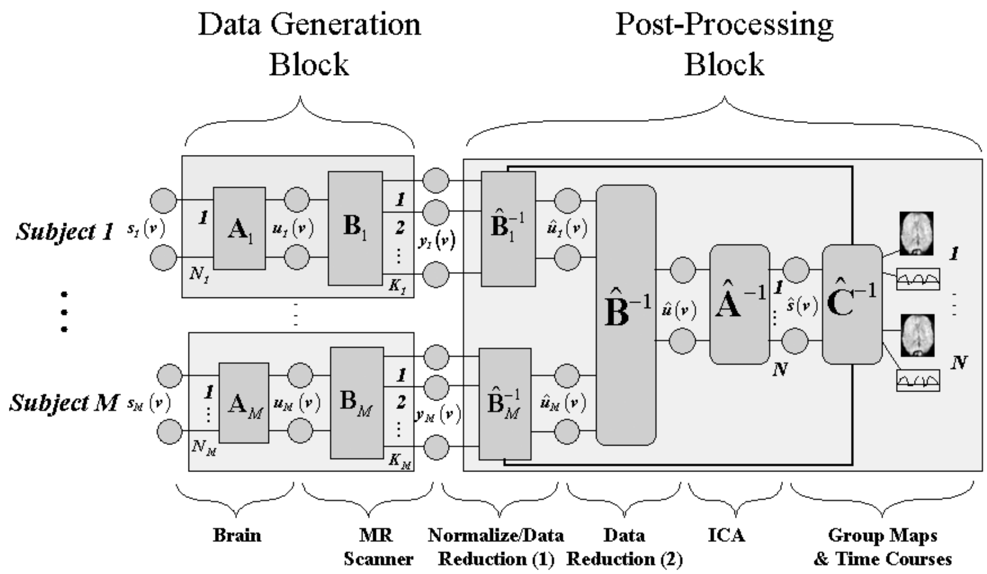
Abstract

Introduction: Independent component analysis (ICA) has been used to analyze single-subject fMRI data sets (1,2). A principal advantage of this approach is its applicability to cognitive paradigms for which detailed models of brain activity are not available. However, unlike univariate methods (e.g., regression, K-S statistics), ICA does not naturally generalize to a method suitable for drawing inferences about groups of subjects. We present here for the first time a method for drawing group inferences using ICA of fMRI data, and its application to a simple visual paradigm.

Theory: We assume a set of independent hemodynamic source locations in the brain (indicated by *s_i(v)* for the *vth* voxel in the *ith* subject) which are linearly mixed by their hemodynamic time courses. This linear mixing is represented by the matrix **A_i** and results in *u_i(v)*. We assume *K_i* time points were acquired and that there are more time points than brain sources. The fMRI sampling of the brain's hemodynamics results in *y_i(v)*. Our goal then is to estimate the hemodynamic sources. Our method contains three stages: (a) spatial normalization and data reduction, (b) independent source estimation, (c) group inference.



Methods: Our paradigm was an 8 Hz reversing checkerboard pattern presented intermittently in the left and right visual fields (3). Subjects were instructed to maintain focus on a central crosshair. 360 functional scan were acquired (EPI, TR=1s, TE=39ms, fov=24cm, 64 x 64, st=5.5 mm, 9 slices).

The images were imported into SPM99, normalized into a Tailarach template (4,5), and reduced to thirty dimensions using principal component analysis (PCA). Data from all subjects was then concatenated. This aggregate data was reduced using PCA to a number of sources estimated from standard information theoretic methods (6). ICA then yielded a set of aggregate components and time courses. Subject-specific component maps are reconstructed from the aggregate ICA components. A "random effects" inference is used to create group ICA maps by entering the magnitudes of the subject-specific components into one-sample t-tests.

Results: Estimation indicated twenty-four components existed within the aggregate data. Group ICA maps resembled individual subject maps but were considerably smoother (much like a group map produced using SPM). Primary visual areas were consistently task-related while bilateral visual association and frontal areas were transiently task-related. Additionally we identified visual areas anterior to the calcarine sulcus which were not task related but were correlated with one another.

Conclusion: This work provides a straightforward, computationally reasonable method for making group inferences using independent component analysis. We demonstrate this method in a visual stimulation experiment, and identify several distinct visual areas which were either consistently task-related, transiently task-related, or correlated, but non task-related.

References: 1. McKeown M, et al., Hum.Brain Mapp. 6, 160-188 (1998). 2. Bell A and Sejnowski, T Neural Computation 7, 1129-1159 (1995). 3. Calhoun V and Pekar J, NeuroImage 11:S682 (2000), 4. Talairach J and Tournoux P, Thieme, Stuttgart (1988). 5. Worsley K and Friston K, Neuroimage 2:173-181 (1995). 6. Karhunen J et al., Int J Neural Syst 8:219-237 (1997).