Resting State ICA Enhanced with Multi-Echo fMRI

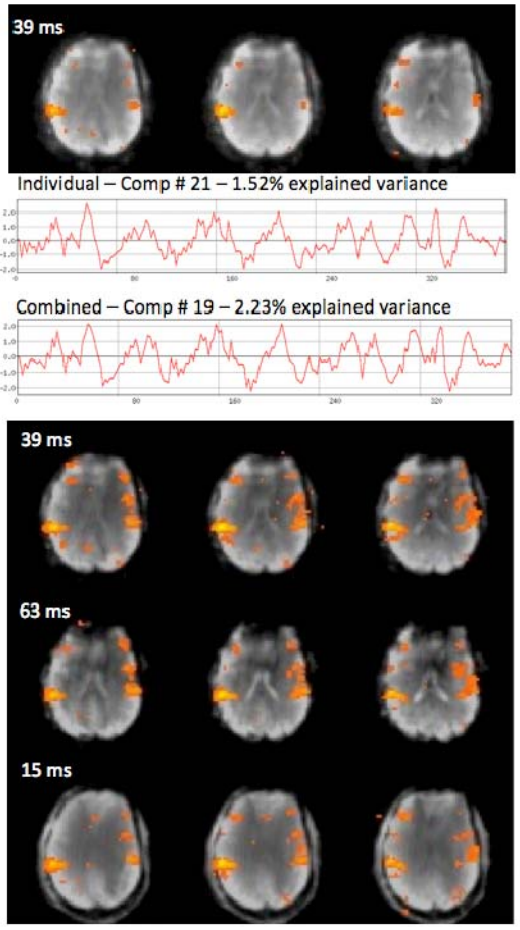
P. Kundu[1], and P. Bandettini[2]
[1]Laboratory of Brain and Cognition, NIMH, Bethesda, MD, United States, [2]NIMH

Introduction

Independent Components Analysis (ICA) uses mutual information to reduce an fMRI dataset to a small group of source timecourses and corresponding localization maps. Resting state network (RSN) activity can then be distinguished from noise sources based on gray matter localization and temporal smoothness. In practice, components frequently have equivocal localization and mixed frequency temporal character. Providing ICA more temporal data acquired from longer resting fMRI scans alleviates this problem, but this is uneconomical. It is proposed that multi-echo (ME) fMRI can do the same while maintaining short scan times. ME fMRI samples signal at several echo-times (TE) during T2* relaxation, providing multiple fMRI timecourses of different BOLD contrasts for the same period. Since robust hemodynamic activity should be expressed across all contrasts within the TE range for BOLD, providing fMRI data of several echo times should improve ICA decomposition by increasing the representation of a true hemodynamic source and decreasing the relative ratios of TE-specific RF noise and weighting contribution of non-hemodynamic physiological signal to some TEs over others.

Method

Presented are resting data collected with a 3Tesla GE HDx MRI scanner with a 16channel brain array (Nova Medical). Subjects were scanned with SENSE multi-echo ge EPI: reduction factor=2, 3 echoes, 64x64, FOV/slice=240/3mm. TEs=(15ms,39ms,63ms), and five TRs: (400ms - 2000ms). Images were reconstructed from k-space data with a SENSE reconstruction developed in-house. Volumes of three 3.5mm thick axial slices per parameter combination were collected, covering the prefrontal, ventral sensorimotor, inferior parietal, precuneus, and occipital regions. The first 8 seconds were omitted as signal reached steady state, and rigid body motion correction parameters of signal acquired with the 39ms TE were used to register datasets of the other TEs. Each dataset was separately blurred with 5mm FWHM Gaussian kernel, and then vertically concatenated. This was input to FSL's MELODIC with all preprocessing and registration options disabled except for a highpass filter for 100 sec. The blurred 39ms TE dataset was decomposed individually for comparison.



Results

Compared to ICA on timecourse data for a single TE of 39 msec, ICA on concatenated 15,39, and 63 msec ME fMRI data provides fewer components indicating better separation (48 versus 69 in figure), and they are less equivocal in localization and temporal smoothness. It also provides the novel measure of empirical component validation that is expression of a single timecourse in volumes of different BOLD contrasts. It is found that: neural and motion components are expressed across all BOLD contrasts, a few temporal components with mixed frequency character have varied spatial expression across contrasts thus invalidating them, others have consistent expression, anticorrelated networks can be consistent across contrasts supporting their validity, and certain artifacts of strong spatial contiguity but ambiguous localization are specific to a single TE and thus likely artifact. These findings reproduced at all TRs starting at 400 msec and across subjects.

Figure (left=right), TR=2000msec
It is shown that a component resolved with data from only TE=39ms has equivocal expression in the left premotor, motor, and parietal cortices compared to the right. The combined data from ME fMRI clearly show a bilateral and unequivocal fronto-parietal network, and at a higher percentage of explained variance.

Discussion

It is shown that combining timecourse data of multiple TEs from a ME fMRI acquisition greatly increases component separation quality without increasing scan time. It also provides an empirical measure of component validity, heretofore lacking in model-independent component analysis. This is a crucial finding towards the clinical translation of resting state fMRI.