A Method for Detecting 'Meaningful' Components in Independent Component Analyses of fMRI Data

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Background & Objective: Independent component analysis (ICA) permits the blind exploratory analysis of fMRI data into spatially independent maps and their corresponding time courses. However, interpretation of the resulting components – in particular, distinguishing "meaningful" (*i.e.,* neurobiologically and biophysically reasonable) components from noise and artifacts – is not trivial, and has generally been done by expert examination of each map (*e.g.,* by comparison to neuroanatomical regions of interest) and time course (*e.g.,* by comparison to paradigm timing). We present a simple approach for sorting components, which reveals meaningful components, by assessing resemblance between components estimated from all the data, and those estimated from only the odd-numbered time points.

Methods: ***Maximum Mean Correlation between ICA Estimations*** For each data set, two ICA estimations are performed: On all the data ("ALL"), and on the odd time point data ("ODD"). Temporal and spatial correlations are computed between each ALL component and each ODD component; we define the average of these as the mean correlation. The maximum mean correlation for each ALL component, with respect to the ODD components, is used to sort the ALL components.

Methods: ***Data Acquisition*** Data were acquired on a Philips 3.0 Tesla scanner, using a multi-element receiver coil to allow partially parallel image acceleration. Blood oxygenation level dependent (BOLD) fMRI data were acquired using single-shot SENSE EPI with whole-brain coverage, a SENSE acceleration factor of 2.0, and a TR of 2.0 s. For the hybrid simulations (see below) "resting state" (eyes open) data were acquired at a nominal spatial resolution of 2 x 2 x 3.6 mm^3 for 3 min 28 s. For the rapid eye movement (REM) sleep study [1], data were acquired at a nominal spatial resolution of $(3.75\ mm)^3$. Eye movements were observed using video monitoring; data acquisition was started when REMs were observed and for as long as they were maintained. For this report, we used REM data of duration 6 min 14 s.

Methods: ***Simulations*** The "resting state" data were first spatially normalized and subsampled into MNI space, and then hybrid data were generated by adding simulated signals, at various strengths, to specific regions of the resulting data.

Methods: ***Analysis*** Preprocessing was accomplished using FSL [2]: masking of non-brain voxels; voxel-wise de-meaning; normalization of voxel-wise variance; slice-time correction; motion correction; temporal high-pass filtering. ICA was performed using MELODIC (v. 2.0) [3], including automatic estimation of dimensionality. Resulting maps were thresholded at the 0.5 level. For each study, separate ALL and ODD ICA estimations were performed; then ALL components were ranked using their maximum mean correlation with respect to the ODD components.

Results: Figure 1A plots component rankings for the hybrid simulated data. The top-ranked component captures the simulated source (see figure 1B), while the next five highest ranked components appear meaningful: the maps resemble familiar functional brain regions and/or previously reported "resting state components" [4], and the time courses contain power predominantly at low frequencies consistent with hemodynamically-modulated BOLD signals. Conversely, the eight lowest-ranked components do not appear meaningful: their maps either depict widely distributed bi-phasic ("salt and pepper") signals, or appear consistent with pulsation or bulk motion, while their time courses contain strong high-frequency signals consistent with noise and/or motion, but not with hemodynamically-modulated BOLD signals. Figure 2A plots component rankings for the REM sleep data. Figure 2B shows that high-ranked components, but not low-ranked components, appear to depict neurobiologically and biophysically reasonable BOLD fMRI signals reflecting neuronal activity during REM sleep.

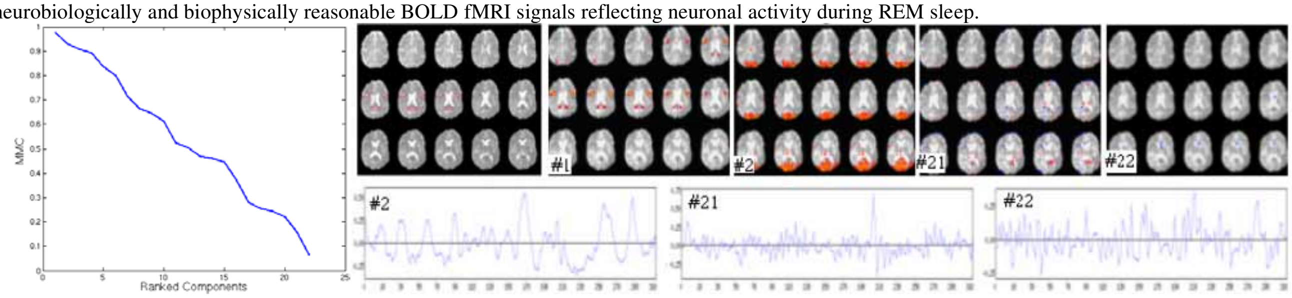

Figure 1. Components from hybrid data: **A**) Plot of maximum mean correlation ("MMC") rankings; **B**) Location of simulated data (red boxes in first sub-figure); maps of two highest ranked and two lowest ranked components; time courses of second-ranked and two lowest-ranked components. Shown are map slices 31-45.

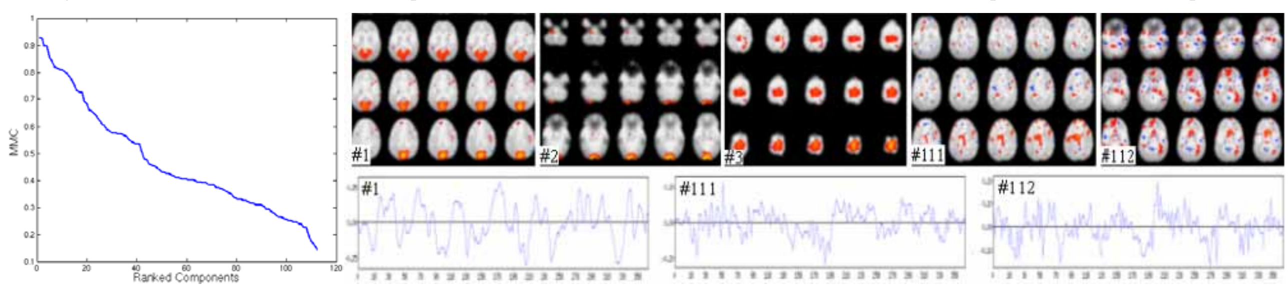

Figure 2. Components from REM data: **A**) Plot of maximum mean correlation ("MMC") rankings; **B**) Maps of three highest ranked and two lowest-ranked components; time courses of highest-ranked and two lowest-ranked components. Shown are map slices 36-50, 16-30, 61-75, 36-50, and 26-40, respectively.

Discussion: McKeown et al., performed ICA separately on the odd and even time points of fMRI data, then used spatial correlation of the resulting maps to demonstrate reproducibility of the "consistently task related" component [5]. Our approach can be seen as a generalization of their findings. We have shown, using hybrid data and REM sleep data, that meaningful components are those which resemble components estimated separately from only the odd time point data. This simple approach to the detection of meaningful components from ICA of fMRI data is expected to have wide applicability.

References: **1**. C.C.-H. Hong et al., Proc. Ann. Mtg. ISMRM 2007, submitted. **2.** http:// www.fmrib.ox.ac.uk/fsl. **3.** Beckmann & Smith, IEEE Trans. Med. Imag. 23:137, 2004. **4.** Beckmann et al., Phil. Trans. Roy. Soc. B. 360:1001, 2003. **5.** McKeown et al., Hum. Brain Mapp. 6:160, 1998.