The interaction of physiological noise correction with multi and single echo ICA denoising

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Target audience: Researchers using fMRI data in resting state and task interested in removing the effects of physiological noise.

Introduction: Physiological noise removal is an important part of the fMRI preprocessing pipeline, but the collection of good physiological data adds an extra complication to data acquisition. Independent components analysis (ICA) offers a way to denoise the signal in a data driven fashion (Kochiyama, 2005), and we compare two methods, FIX (Salimi-Khorshidi, 2014) and MEICA (Kundu, 2012), in contrast to RETROICOR, a standard method of physiological noise removal. FIX attempts to remove "non-signal" components by prior identification, and MEICA classifies BOLD and non-BOLD components using BOLD-TE proportionality in multi-echo data. Prior identification of the components can be tedious and involves guesswork using previous spatial and temporal information. MEICA conservatively retains physiological noise if it has a BOLD signature. We seek to determine how much physiological noise is left in the data after FIX and MEICA denoising, if any, and move towards an understanding of when direct physiological noise corrections are required.

Methods: 10 normal subjects (4 males, ages 22-36, median 23, mean 27) were scanned on a Siemens Skyra 3T scanner using a 20 channel coil with MPRAGE (res: 0.9mm) and multi-echo fMRI EPI scans (ipat2, res: 3.5 mm, 25 slices, FA 90, TR 2 s, TEs: 13,30,46 ms). The visual task was a whole field flashing checkerboard at 4 Hz with a central fixation cross displayed for 80 s and turned off for the second 80s of the scan. Subjects were instructed to fixate the cross in the middle of the screen for the duration of the run. The multi-echo data was processed using MEICA, which decomposes the fMRI data using ICA and distinguishes BOLD and non-BOLD components based on a test of linear TE- dependence. Removing all non TE-dependent components specifically removed non- BOLD drifts while preserving BOLD baseline signal changes. For comparison, each echo was separately preprocessed with physiological noise correction having RETROICOR regressors generated using McRetrots in AFNI (Cox, 1996) and regressed out. The middle echo data were processed using FIX. The power spectral density of the RETROICOR regressors was calculated, and the peak frequencies of the cardiac and respiratory traces were identified. Spatial maps of the relative power at these frequencies were made for each of the preprocessed data types. The top 5% of voxels in the preprocessing without physiological noise was used as a mask to determine the mean power value in each of the preprocessing streams at this frequency for quantitative comparison.

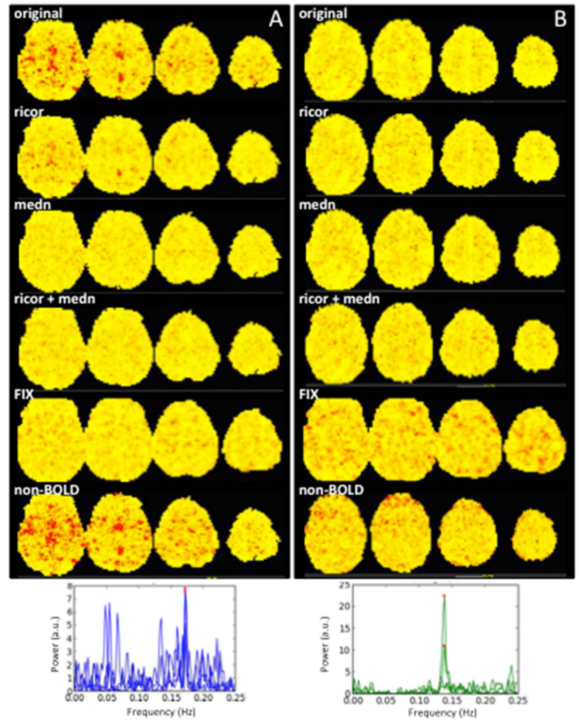

Figure 1. Example cardiac artifact reduction in a representative subject for 5 processing methods.

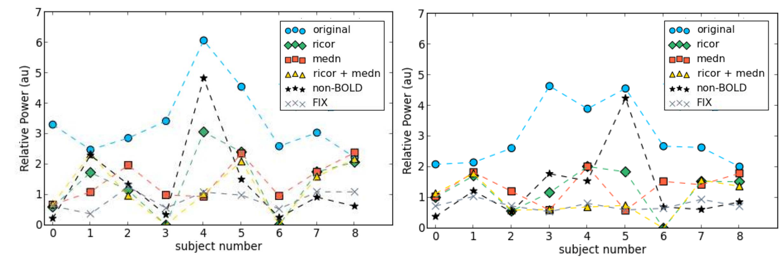

Figure 2. Power values for cardiac (left) and respiratory artifact frequencies .

Results: Figure 1 A, B illustrate axial slices from a representative subject showing an overlay of the power spectrum at frequencies containing cardiac and respiratory artifacts as indicated by the power spectrum of the cardiac RETROICOR regressors shown below. Focal cardiac artifacts are visibly reduced in all methods, while respiratory artifacts are somewhat diminished. Figure 2 shows the mean power spectral values from the 5% mask in each of the preprocessed data types at the cardiac peak frequency. The decrease in the power at the physiological noise frequencies is indicative that the ICA denoising methods are dealing effectively with physiological noise to a similar extent as RETROICOR. Figure 3 shows beta values for the task illustrating that no task component was regressed out and fit values are similar to those obtained using RETROICOR. One concern about ICA denoising methods is if the spatial pattern of the noise overlaps with networks of interest these may also remain mixed in. It remains to be investigated how much the physiological contributions lie in the BOLD spectrum. It is also possible to use an ICA-trained set from the ME decomposition in combination with FIX data to reduce the time required to generate a hand trained set and improve the results.

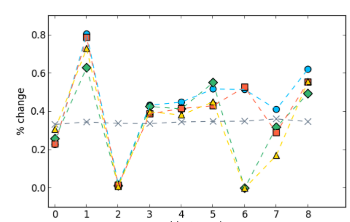

Figure 3. Task correlated beta values by subject

Conclusions: MEICA reduces cardiac artifact well, and diminishes respiratory artifacts in most cases while retaining all task components automatically. FIX also denoises the data well, but needs optimization for best performance. The use of RETROICOR regressors prior to ICA denoising may be beneficial.

References: Cox R (1996) Comput Biomed Res.29(3):162-73; Glover et al. (2000) Magn Reson Med. 44(1):162-7.; Kochiyama T et al, (2005) Neuroimage, 25(3):802-14;Kundu, P et al.(2012) Neuroimage 60(3) 1759; Salimi-Khorshidi,,G et al. (2014) NeuroImage, 90:449-68