# Spatiotemporal Dynamics of Low Frequency Fluctuations in BOLD fMRI of Rats and Humans

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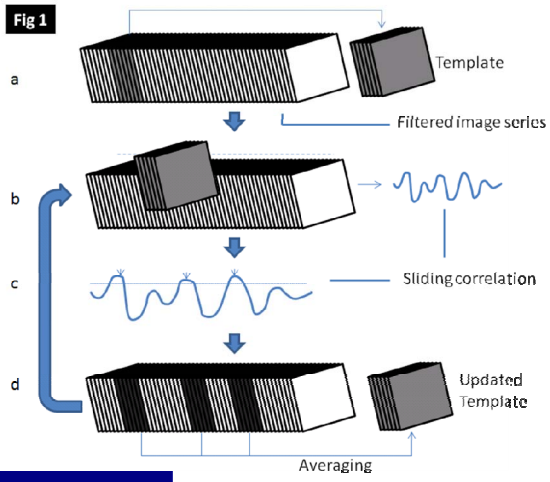
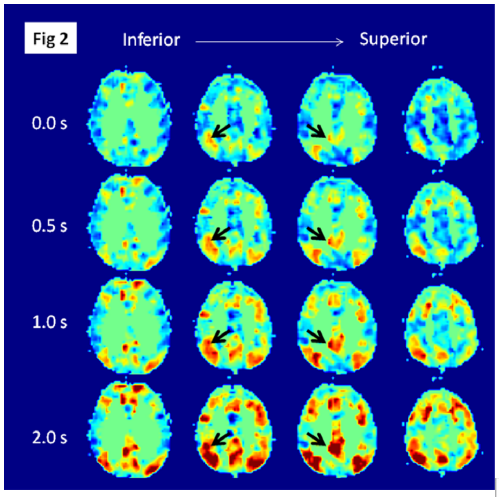
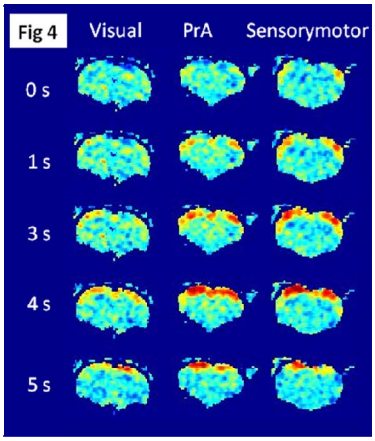
**Introduction:** Functional connectivity and spontaneous low frequency fluctuations (LFFs) in the BOLD signal [1] have gained considerable interest among the fMRI and neuroscience communities in the past few years. Current techniques for analyzing spontaneous LFFs (correlation maps, ICA, clustering) assume steady state and do not provide insight into spatiotemporal dynamics of the LFFs [1, 2, 3]. A recent investigation into spatiotemporal dynamics of LFFs showed presence of propagating waves in the rat cortex using visual inspection of the filtered data [4]. This work investigates presence of spatiotemporal patterns in multislice data obtained from humans and rats using a novel automatic pattern finding approach.

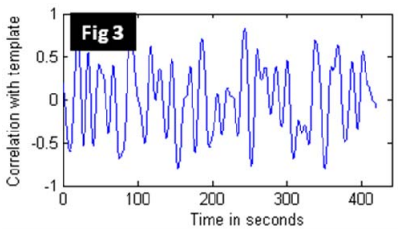


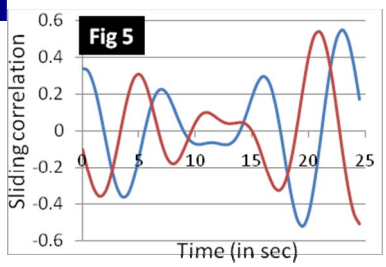

**Methods:** *Animal Imaging:* Imaging was performed on 9.4T Bruker scanner. The rats (n = 8) were sedated using medetomidine. For each rat, a series of gradient echo EPI images was acquired of 4-5 coronal slices with following parameters: TR = 500 ms, TE = 20 ms, matrix size = 64x64, in-plane resolution = 300-400 microns, 1200 repetitions. The slices covered areas including somatosensory and visual cortices, caudate-putamen (CP) and parietal association area (PrA). *Human Imaging:* Healthy adult subjects were scanned a 3T Siemens scanner. The subjects were asked to lie quietly in the scanner with their eyes closed. Short TR (300ms) EPI image series were acquired with 4 slices, 1200 repetitions. Horizontal slices parallel to line joining anterior and posterior commissures were obtained. *Preprocessing* included slice time-correction, spatial blurring, filtering, and normalizing of each time series to unit variance. White matter signal was regressed out for human data. *Algorithm for automatic detection of dynamic patterns:* A chunk of consecutive images starting at a random time is selected from the preprocessed image series to serve as template (fig 1a). The duration of the template is pre-defined (termed as window length – WL). Sliding correlation between the filtered image series and the template is obtained (fig 1b). Peaks are detected in the thresholded sliding correlation (fig 1c). Chunks of images corresponding to the peaks correlation values are averaged in order to obtain updated template (fig 1d). Steps b-d shown in fig 1are repeated until convergence is achieved. The template resulting in convergence represents the detected spatiotemporal pattern. The analysis can be restricted to certain regions of interest (ROIs). ROIs defined in cortex were used for human and rat data. Also, rat data was analyzed with ROI placed in bilateral CP.




**Results and Discussion:** Fig 2 shows a few time-points of the propagation pattern detected in a human subject. The pattern shows propagation of high intensity in the areas comprising default mode network. Some regions within the default mode network seem to be the 'sources' of this propagating pattern (a few of which are indicated on the figure). Fig 3 shows the sliding correlation with the final template. Peaks with high correlation can be seen, representing the occurrence of the pattern (fig 3). Propagating waves from lateral areas to medial areas of the cortex were seen in all the slices for the rat data (fig 4, only 3 slices shown). This result confirms the presence of waves from SII to MI as reported in [4]. Also it extends that work by demonstrating the presence of the waves in PrA and visual cortices. ROI based in CP resulted in propagation patterns with different timing (not shown in this abstract). Sliding correlation values were highly similar (cc > 0.7) for window lengths ranging from 15 to 27 frames. Different starting locations for the initial template result in the patterns with time shift, as evident from the time-shifted peaks in the correlation with the final template (fig 5).




In conclusion, presence of propagating patterns is demonstrated in LFFs in multislice BOLD fMRI of rodents and humans and rats using a novel approach for detecting these patterns. In depth study these patterns can reveal more information about the origin and significance of LFFs. For example, identification of sources of the high intensity can identify possible drivers / regions receiving input from the drivers of the LFFs in BOLD.

**References: :** [1] Biswal, B et al. Magn Res Med 1995; 34:537-541
[2] Van De Ven, VG et al. Hum. Brain Mapp. 2004; 22:165-178
[3] Cordes, D et al. Magn. Res. Imaging 2002; 20:305-307
[4] Majeed et al. JMRI 2009 ; 30:384-393