BRAIN TISSUE SPECIFIC SPATIAL DISTRIBUTION OF FMRI PHYSIOLOGICAL NOISE: CSF NOISE HIGH OR LOW?

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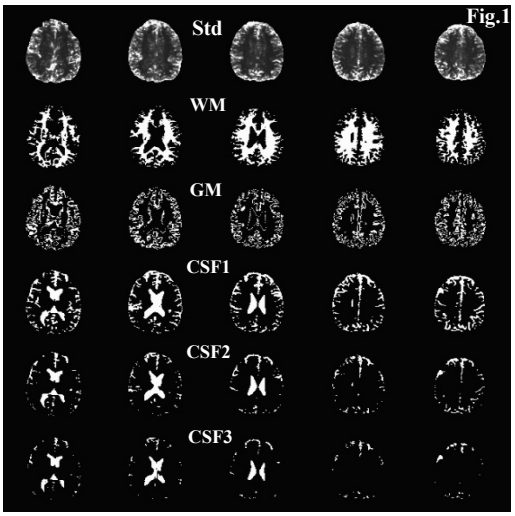
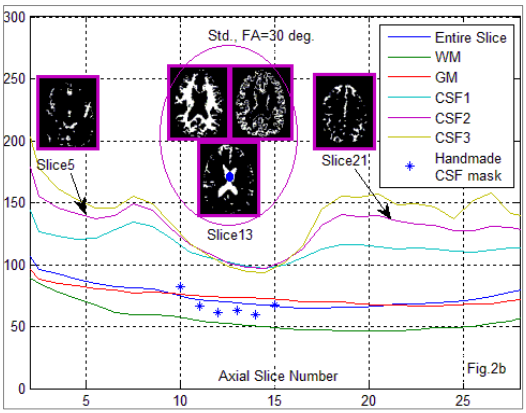
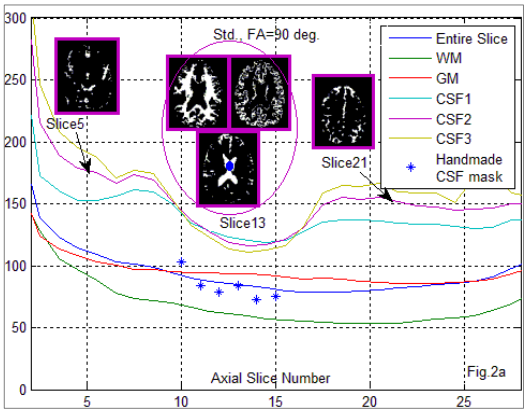
INTRODUCTION: BOLD fMRI data includes two major sources of noise: thermal/system and physiological [1,2]. It has been consistently shown that physiological noise contribution in fMRI data is significantly greater in gray matter (GM) than white matter (WM) and with evidence of the largest noise level in cerebrospinal fluid (CSF) [2,3]. We hypothesize that surprisingly large physiological noise level in CSF compartments is due to partial volume effects with GM and brain vasculature. To test this we investigated different brain tissues' physiological noise spatial distributions in the resting brain. We used a T_1-based brain tissue segmentation method which utilizes T_1 differences between CSF, GM and WM [2] on our fMRI data. To further elucidate physiological noise levels in CSF compartments and partial volume effects from other brain tissues, we increased the T_1 threshold to obtain multiple CSF masks, as a longer T_1 threshold includes less CSF voxels with partial volume. Together with a spatial distribution of noise level across different slices and different T_1 threshold values we showed that CSF noise exhibits strong spatial dependence. In axial slices with cerebral ventricles CSF noise level was the lowest, whereas it was highest in more inferior and superior slices.

METHODS: General Electric Discovery MR750 3 Tesla MRI scanner and the standard 8ch receive-only brain array were used for imaging. For fMRI single-shot gradient-recalled EPI was used. The imaging parameters were TR/TE=2000/27 ms, FOV/slice thickness=240/2.9mm, SENSE=2, matrix 96×96, BW=250 kHz, thirty axial slices, scan time=360 s. All four male subjects underwent four resting fMRI scans with flip angles of 10°, 30°, 60°, and 90° to further manipulate with physiological noise levels [3]. **Image Processing**: EPI volumes across different runs were aligned to the first volume from the run with FA=90° using AFNI. For each run, the first 5 volumes were neglected to allow the fMRI signal to reach steady state. A temporal standard deviation image (Std) was derived from each voxel's time series. Additionally, for each axial slice the average of the Std across all voxels in the slice were calculated to provide an estimation of the noise level of the entire slice. Furthermore, tissue masks were defined for each subject. The tissue masking was done using the method proposed in [2], which relies on the differences in the T_1 values of gray matter (GM, 1.2s<T_1<1.6s), white matter (WM, T_1<=1.1s), and cerebrospinal fluid (CSF, T_1>=2.0s). To obtain a better estimation of CSF noise, some extra masks with longer T_1 thresholds have been defined. This new T_1 thresholding aids in reducing overlap between CSF and other brain compartments (GM, WM, and vasculature). Therefore, voxels remaining in the new masks, i.e. those with longer T_1, have relatively purer CSF. An additional hand-drawn CSF mask in the ventricles was defined for comparison purposes. Finally, the average temporal "Std" of each slice was computed for WM, GM, and CSF masks.



RESULTS: Fig. 1 shows the Std map in the first row along with GM, WM, CSF1, CSF2, and CSF3 masks in rows 2–6, respectively (FA=90°). Note that the T_1 thresholds for CSF1, CSF2, and CSF3 masks for each subject were set to 2.0, 2.5, and 3.0 seconds, respectively. The average number of voxels in the masks were 41470, 31120, 22335, 10983, 5967, and 457 for WM, GM, CSF1, CSF2, CSF3, and the handmade CSF mask deep inside ventricle, respectively. Figure 2 shows the spatial distribution of noise level (Std) across axial slices (inferior-superior direction) for all used masks with FA=90° and FA=30°. As expected, at the lower flip angle physiological noise decreased in all masks [3]. The CSF compartments show strong noise spatial dependence with prominent and broad minima. Interestingly, higher T_1 thresholds for CSF compartments result in lower noise levels in ventricles and higher noise levels in inferior and superior slices.





DISCUSSION: We showed the spatial distribution of the physiological noise level in different brain compartments. We found that the physiological noise level in CSF compartments is highly spatially dependent in inferior to superior direction, featuring broad minima in axial slices containing ventricles, whereas for WM and GM much weaker dependencies were observed. This finding suggests that indeed CSF partial volume effects with cerebral cortex GM gyri surface in sulci, and especially with cortex surface vasculature, contributes to high physiological noise level observed in the CSF compartments. Therefore, estimation of the CSF physiological noise highly depends on the imaging slice spatial location and the method chosen for extracting CSF compartments. For example, manual selection of a small CSF mask deep within ventricles (mask & Std data marked in **blue** on Fig.2) as compared to one located in sulci and in more superior slice, may results in large differences in physiological noise estimation. Our findings explain the differences in the reported CSF noise levels and consistent values reported for GM and WM compartments [1-5].

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