Utility of T2-Weighted Anatomical Images for fMRI Physiological Noise Visualization

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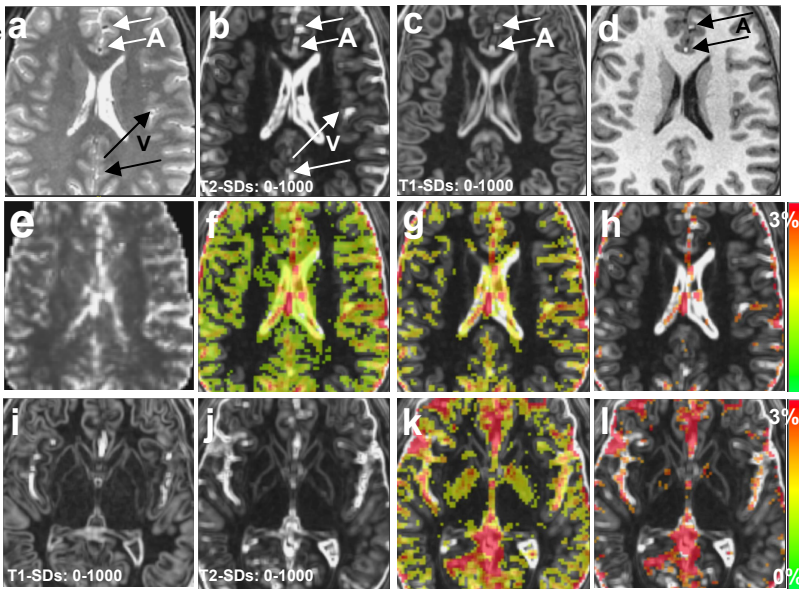
Introduction: Physiological noise is a major source of temporal BOLD fMRI signal variation and a confounding factor in the detection of neuronal activation as well as functional connectivity in fMRI studies [1–3]. Although some of the contributing sources have been identified, including spontaneously BOLD-related low frequency fluctuation and cardiac and respiratory signal modulation, the physical mechanisms of such "non-white" noise remain poorly understood [2–4]. The contribution of the physiological noise to temporal noise in fMRI time courses also vary between different brain tissues, being the largest in cerebrospinal fluid (CSF) and grey matter (GM) and the smallest in white matter (WM) [5]. Here we will show the utility of anatomical high-resolution T2-weighted fast-spin-echo (FSE) images to predict and visualize the brain areas where physiological noise, as measured during fMRI, will be present.

Methods: Three human subjects were scanned. General Electric Discovery MR750 3Tesla MRI scanner and the standard 8ch brain array were used. Anatomical imaging common parameters: axial plane, FOV/slice=240/1.2 mm, matrix 256x256, SENSE=2; T2-weighted FSE sequence: TR/TE=8597/88 ms, BW=15.6 kHz, echo train=24, 105 slices, scan time 4min 2sec; T1-weighted MPRAGE sequence: TR/TE=5/1.9 ms, TI=725ms, flip=8°, BW=31.2 kHz, scan time 4min 58sec; resting fMRI gradient EPI: SENSE=2, axial plane, FOV/slice=240/2.9mm, 96x96, TR=/TE=2000/30ms, flip=78°, BW=250kHz, 34 slices, reps=264, scan time 6min 48sec. Image processing: EPI and FSE images were realigned to MPRAGE volume. Both T1- and T2-weighted anatomical images were further processed as follows: for each voxel in an axial slice the standard deviation from all neighboring voxel intensities separated by r=1 voxel in all three dimensions were computed and new "spatial" SD_s images were formed, i.e. Tk-SD_s(x,y,z) = stddev(Image[x-1..x+1][y-1..y+1][z-1..z+1]), k=1,2. Individual voxel values in the SD_s images were computed from the surrounding volume (at "fMRI grid") which approximately matches EPI/fMRI voxel volume (2.8x2.8x3.6mm^3 versus EPI 2.5x2.5x2.9mm^3). The SD_s images show and enhance the original image areas where there is large signal intensity change between different compartments, e.g. in T2 images CSF (bright)/GM (grey) and GM (grey)/vessels (dark). The T2-based SD_s images especially enhance visualization of CSF and vasculature presence because of the high contrast between CSF (high signal) and veins/arteries (low signal). Our prediction is that the bright regions on the T2-based SD_s images ("hot spots" of high spatial standard deviation values predominantly due to CSF and vasculature presence) will reflect high temporal signal variation as measured during fMRI scans. As a measure of physiological noise we computed, on pixel-wise basis, the standard deviation image from fMRI time series (SD_t), i.e SD_t(x,y,z) = stddev(EPI[x][y][z][5..264]). We expect that temporal SD_t and T2-based spatial SD_s images should have similar appearance andshould overlap.



Results and Discussion: Upper images show representative examples of T1-based (b) and T2-based (c) SD_s images (both with r=1) produced from FSE (a) and MPRAGE (d) images, respectively. Arrows indicate examples of identified arteries (A both on FSE and MPRAGE) and veins (V on FSE). Note that T2-based SD_s (b) shows more white areas than T1-based SD_s (c), due to the larger signal difference between CSF and vessels on the FSE image. Middle images show corresponding SD_t image (e) (expressed in percent signal changes, display 0–3%) computed from fMRI/EPI resting run and T2-based SD_s with SD_t overlay with thresholds at th=0.8% (f), 1.1% (g) and 2% (h). Bottom images show T1-based (i) and T2-based (j) SD_s from another slice and the corresponding T2-based SD_s with SD_t overlay with threshold at th=1.1% (k) and 2.0% (l). Indeed SD_t with th=1.1% matches well with the SD_s images computed from FSE (g, k). At largest th=2.0% there is still overlap of the hot spots from SD_t and T2-based SD_s, which indicates vasculature and surrounding CSF as the main sources of the physiological noise in those areas.

Conclusion: We introduced T1- and T2-based SD_s images that enhance spatial signal variation between different brain compartments: CSF/GM/WM and/or vasculature. The T2-based SD_s image, computed approximately to the fMRI grid, predicts well the brain areas where the fMRI signal temporal variation will be present. The hot spots on the T2-based SD_s are predominantly due to CSF and/or vasculature presence. Those regions indeed reflected the high physiological noise as shown on temporal standard deviation SD_t images from resting fMRI run. Results suggest that alongside the standard T1-based anatomical reference volume the addition of a short (approximately five-minute) high-resolution whole-brain T2-weighted scan to the fMRI experiments can be beneficially utilized to predict, map, and identify underlying brain compartments in the physiological noise spatial distribution.

References:1) Kruger et al. MRM 46,631,2001; 2)Birn et al, Neuroimage 31,1536,2006; 3) Chang et al. Neuroimage 44,857,2009; 4)van Buren et al. HBM 30,3031,2009; 5) Bodurka et al. Neuroimage 34,542,2007.