High spatio-temporal resolution imaging of resting state fluctuations at 7T

N. Petridou[1], A. Schäfer[1], P. Gowland[1], and R. Bowtell[1]
[1]SPMMRC, University of Nottingham, Nottingham, United Kingdom

Introduction

It has been shown that physiological fluctuations consist of BOLD and non-BOLD related noise and that these fluctuations are minimized with increasing resolution [1-3]. Here we investigate the spatial/temporal nature of the BOLD and non BOLD resting state fluctuations at 7T, using a spatial resolution where physiological and thermal noise are similar in magnitude [1], multiple echo-times, and a TR which is short enough to sample physiological fluctuations adequately. Both magnitude and phase fluctuations were examined.

Methods

Five subjects were scanned on a Philips 7T using a quadrature head coil and a single-shot EPI (TR: 300ms, flip 36^0, spoiled). Three coronal slices were acquired from the center to posterior part of the brain (15mm slice gap). The spatial resolution was 1.6x1.6x1.5 mm and 2x2x2 mm (FOV: 128mm). Data were acquired at TE's of 17,24,30,35,40, and 50 ms, in separate runs (500 images/run). Thermal noise measurements (0^0 flip angle EPI) and a venogram were acquired for each subject (3D spoiled gradient-echo, EPI factor:3, TE:30ms, TR:50ms, flip:16^0, 1x1x1). Cardiac pulse (pulse oximeter) and respiration (respiratory belt) data were recorded for all runs to identify the corresponding fluctuations in the time series data. The data were processed using AFNI (NIMH/NIH), FSL (FMRIB/Oxford), and in-house algorithms. For each resolution, data sets were coregistered to the data set acquired with TE = 24ms and corrected for motion and linear drift. Power spectra were calculated per voxel. Maps showing the fluctuations at cardiac and respiratory frequencies were obtained by integrating the relevant peak over a spectral range of ~0.15Hz. Similarly, low frequency maps were obtained for the ~0-0.03Hz and ~0.03-0.13Hz ranges. The remaining spectral range was segmented in 0.15Hz bands and the TE dependence for all frequencies was assessed for ROI's obtained from gray and white matter. Similar spectral analysis was performed on the phase images after unwrapping and linear drift correction. Additionally, BOLD and non-BOLD physiological noise was computed as in ref. [3] before and after application of RETROICOR [4].

Results

The computed BOLD and non-BOLD noise behavior at each resolution was found to be in agreement with published results [1]. The spectral analysis of magnitude data showed that time series fluctuations mainly consisted of low frequency fluctuations in CSF, vessels, and gray matter (Figure 1). In gray matter, low frequency fluctuations exhibited a BOLD-like TE dependence (Figure 2). No TE dependence was observed in other frequency bands. Similar results were obtained for both resolutions. Filtering out frequencies <0.16Hz resulted in a ~5% and ~15% reduction of the computed BOLD noise for the 3.84 and 8 mm^3 resolution data respectively. The amplitude of all fluctuations increased with TE in the phase data as expected, although this increase was greater than that predicted from the 1/TSNR variation. Furthermore in contrast to the magnitude data, the phase data showed significant fluctuations at the respiratory frequency. Low frequency power showed a small increase for TE:30ms (~T2*) for gray matter (Figure 2).

Conclusion

The results show that the BOLD related noise contribution occurs below 0.13Hz and that BOLD-like fluctuations persist at spatial resolutions where physiological noise and thermal noise are equivalent in strength. The results also show that such BOLD noise may affect phase data. Future work will include further exploration of the phase noise and assessment of the contribution of respiration/cardiac rate changes in low frequency fluctuations [5,6] for the short TR and resolution used here.

References: 1] Triantafyllou et al., NeuroImage 26:243–250, 2005, 2] Bodurka et al. NeuroImage 34(2):542-9, 2007, 3] Kruger et al. MRM 46:631–637, 2001, 4] Glover et al. MRM 44(1):162-7, 2000, 5] Birn et al. NeuroImage 31: 1536-48, 2006, 6] Shmueli et al. NeuroImage 38(2): 306-320, 2007

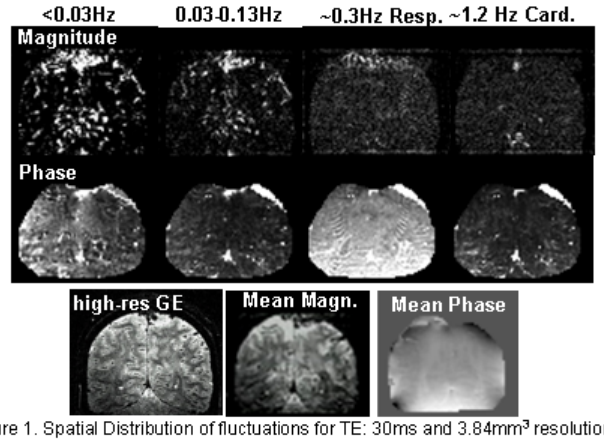

Figure 1. Spatial Distribution of fluctuations for TE: 30ms and 3.84mm^3 resolution (n=1). Intensity scale is the same for the frequency maps but different for magn. and phase. Bottom row shows the high resolution gradient echo image (veno) for the same slice and the EPI mean time series magnitude and phase image.

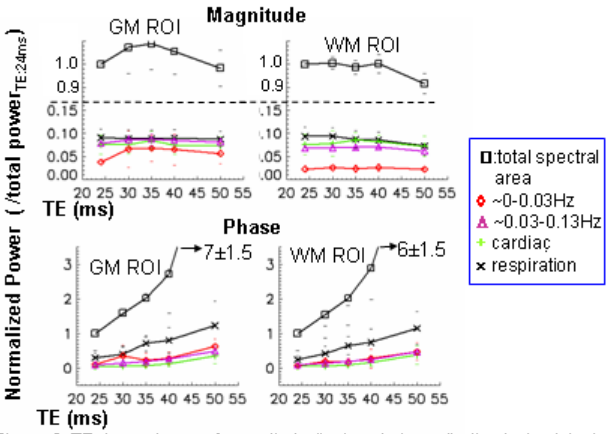

Figure 2. TE dependence of magnitude (top) and phase (bottom) physiologic fluctuations for Gray (GM) and White Matter (WM) ROIs, for the 3.84mm^3 resolution. Error marks show the st.dev. across subjects (n=5)