B0 Dependence of Physiological Noise in BOLD fMRI

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Introduction: With the advent of high field MRI technology, there is continuously growing interest in conducting BOLD fMRI and resting-state connectivity mapping at higher field strength. This is founded on a number of anticipated advantages, such as, gains in SNR and improved sensitivity in detecting brain activations. However, physiological noises are also amplified with the increased signal strength. Previous studies on this topic have been more focused on modeling how the different data acquisition parameters, such as TE and spatial resolution affect the total level of physiological noise [1,2]. Here we propose a straightforward procedure to remove cardiac and respiratory related signal fluctuations and characterize the remaining physiological noise level as a function of hardware settings, while keeping the data acquisition protocol constant and using parameters similar to those used in realistic fMRI studies.

Materials and Method: The study involved a total of 4 MRI scanners with 7 different hardware configurations and 18 normal volunteers. More details are summarized in Table 1. The same data acquisition protocol based on a single-shot 2D EPI technique was used on the different scanners and it included: 1) thermal noise measurement by either turn off the RF power or by setting the flip angle to zero; 2) duplicated measurements of time series of T_2*-weighted MRI. The essential acquisition parameters are the followings: TR=2s, matrix size=128×96, flip angle= 90^o, FOV=240×180mm^2, 20 transverse slices of 2 mm thick, and 150 time frames. An acceleration factor of 2 was used along the phase encoding direction to reduce readout duration and susceptibility related artifacts. The TE parameters used at the different field strengths were adjusted to be approximately equal to the T_2^* values for the corresponding magnetic field strength, as usually done in real fMRI studies to achieve the optimal BOLD contrast. Therefore, TE used for the 1.5, 3, and 7T measurements were 50, 40, and 25ms, respectively. Cardiac and respiratory signals were simultaneously recorded. For the data processing, the following procedure was used: 1) head motion correction by using the AFNI *3dVolreg* program; 2) linear regression analysis using the AFNI *3dDeconvolve* program by including the following regressors: the output motion parameters from *3dvolreg*, the recorded cardiac and respiratory waveforms; 3) removing baseline drift by performing a polynomial fitting up to the order of 3; 4) computing pixel-wise coefficient of variance (std/mean); 5) evaluating average values for grey and white matter in selected ROIs.

Table 1: Hardware configuratoins and studied subject numbers.

Scanner	Siemens 1.5T	Siemens 3T		GE 3T	GE 7T		
Detector	12ch	12ch	32ch	16ch	8ch	24ch	32ch
Subject	3	3	3	12	3	3	3

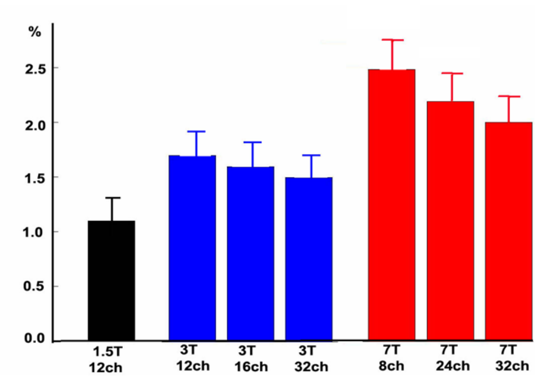

Figure 1: Estimated physiological noise (%).

Results: As shown in Figure 1, the physiological noise in grey matter is significantly increased with the increased magnetic field strength. Comparing 7T with 1.5T, the physiological level at 7T is more than doubled. This suggests that it is essential to develop effective method to reduce physiological noise in order to make most out of a 7T for fMRI studies [4]. As expected, the physiological noise level in white matter is much lower [1,2] and is about one third of that measured in gray matter for most of the hardware settings studied here. The thermal noise is relatively small and constant. It is about 0.3±0.1% in all cases. At a given field strength, the use of a large deter array (more receiving channels) reduces the relative level of the physiological noise in the total signal. Particularly at 7T, the use of 32 channel array reduces the physiological level by about 20% in comparison with the 8 channel array. This is probably due to the use of smaller coil elements in the larger arrays, which reduces the volume contributing noise to individual coil element.

Discussion: Compared with earlier studies [1,2], we used a relatively high spatial resolution by making full use of the improved hardware. Using higher spatial resolution reduces the signal strength and the relative sensitivity to physiological noise. This can be of SNR advantage for time series fMRI data acquired at higher magnetic field [2]. Moreover, the cardiac and respiration cycle related contributions were excluded. The remaining physiological noise may be originated from fluctuations in brain metabolism, perfusion, and spontaneous neuronal activities. Recently, a number of effective approaches have been proposed to further reduce the remaining physiological noise in grey mater by taking advantage of the coherence characteristics [3,4]. Accordingly, the sensitivity for detecting brain activation can be improved by up to 160%. It remains to be confirmed whether this type of denoising benefits also the resting-sate connectivity mapping.

References: [1] Kruger G. *Magn Reson Med* **46**:631 (2001); [2] Triantafyllou C. *Neuroimage* **26**:243 (2005); [3] De Zwart J. et al. *Magn Reson Med* **59**:939 (2008); [4] Bianciardi M., *Neuroimage,* in press (2008).