Dependence of Physiological Noise on MR Signal in GE and HSE BOLD images at 7 T

E. Yacoub[1], K. Ugurbil[1]

[1]Center for Magnetic Resonance Research, University of Minnesota, Minneapolis, MN, United States

Introduction:

In fMRI studies, the sensitivity to the detection of task or stimulus induced signal changes is limited by temporal fluctuations in signal intensity and not solely the SNR of a single image. In Gradient Echo (GE) BOLD based fMRI, previous studies have shown that increases in signal magnitude are accompanied by a proportional increase in temporal noise (associated with physiology) (1), thus imposing a plateau on the sensitivity in fMRI images (2), despite any gains in intrinsic image SNR. Most of the previous work investigating the temporal noise characteristics of MR images has involved the GE BOLD signal. GE BOLD fMRI, at both low and high fields, has been shown to contain significant "non-specific" contributions from larger draining vessels. On the other hand, HSE BOLD images were shown to be highly spatially specific, and relatively immune to non-specific large vessel signals at very high magnetic fields. The source and mechanism of the physiologically induced temporal signal instabilities need not be the same for these two approaches due to the difference in vascular components that contribute to each. Temporal signal-to-ratio is an important factor in the optimization of fMRI studies, specifically in terms of an optimum field strength and /or spatial resolution. In this work, we investigate the differences in the temporal noise characteristics of HSE and GE BOLD images, and their respective dependencies on signal magnitude at 7 T in the human visual cortex.

Methods:

There are many different ways to alter the absolute MR signal in order to asses the dependence of the temporal noise on the signal magnitude. The echo time, flip angle, spatial resolution, or even simply the B1 distribution of the RF coil, all present a means by which the signal intensity can be altered. However, the dependence of the temporal noise on the signal *might* depend on how the signal intensity is altered since spatially incoherent signal fluctuations will average at lower spatial resolutions. In this work, the signal intensity was varied by different methods. First, the spatial resolution hence voxel volume was changed in order to alter the signal intensity. Studies were conducted at 7T using a 12 segment EPI acquisition for GE studies, and a reduced FOV 3 segment acquisition for HSE studies. A TR of 6 s was used and TEs of 50 and 25 msec for HSE and GE images, respectively. The spatial resolution was: 0.5 x 0.5 x 3 mm^3 for both sequences, and lower spatial resolutions were obtained by discarding appropriate outer k-space points from the high resolution data. In a second study, flip angles of 90°, 60°, 40°, and 30° were used at a lower spatial resolution of (1 x 1 x 3 mm^3) with a TR of 2 s and TEs of 50 and 25 msec for the HSE and GE images, respectively. In addition to changing the flip angle and the spatial resolution, the intrinsic distribution of signal intensities due to the B1 inhomogeneity was also used to assess the relationship between signal and noise. The thermal noise was calculated using a separate series of images acquired without any RF power, and in addition an ROI placed outside the brain was also used as a measure for comparison.

Results:

The results from one subject, both GE and HSE data are shown in Fig.1 for the data obtained by changing the spatial resolution. The different colors represent the different in plane spatial resolutions. The noise that is plotted represents the variance of the physiological noise, obtained by subtracting in quadrature the thermal noise (i.e. $\sigma^2 = \sigma_{phys}^2 + \sigma_{Therm}^2$). The noise in the GE data appears to have a significant dependence on the MR signal intensity, unlike the HSE data, which behaves quite differently. In addition, the variance (σ_{phys}^2) in the HSE data depends significantly on spatial resolution, unlike the GE data, which does not. This results in the ratio ($\sigma_{phys} / \sigma_{Therm} \sim 2$) being nearly independent of spatial resolution in the HSE data, and highly dependent in the GE data. The flip angle dependence study gave a similar result.

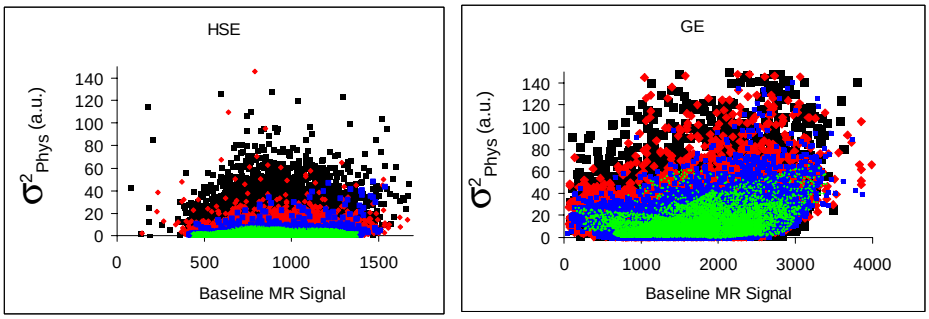

Fig.1 *Scatter plots of pixel variance(calculated as the variance of temporal fluctuations of brain signals in the fMRI time series minus the variance of thermal noise) versus MR signal for different in plane spatial resolutions of HSE (left) and GE (right). The different colors represent the different in plane spatial resolutions, black (0.5 x 0.5 mm^2), red (1.0 x 1.0 mm^2), blue (2.0 x 2.0 mm^2), and green (4.0 x 4.0 mm^2). The MR signal intensity is expressed in arbitrary units (a.u) but the same units were used for all resolutions. Variance is calculated in the same a.u. Images were scaled so that signal intensities covered the same range for the different resolutions. Because of this scaling, variance decreases with decreasing resolution.*

Conclusions:

Our findings from the spatial resolution data, the flip angle data, and the natural distribution of signal intensity variation in the images, all demonstrate that the temporal noise in the GE data has a much *stronger* dependence on the signal magnitude compared to the than HSE. While a dependence on signal magnitude is barely detectable in the HSE data, the temporal noise in the HSE images is not entirely thermal noise. In addition, there is a component of the GE noise that tends to be spatially coherent, while the HSE temporal noise is spatially incoherent at the voxel sizes employed and averages like thermal noise as voxel size is altered. These results indicate that thermal noise characteristics are fundamentally different between HSE and GE BOLD fMRI and that the primary source of the physiological noise in GE BOLD images, unaccounted by post-processing removal strategies, originates from larger vessels. Further increases in the MR signal, for example by going to higher magnetic fields, will result in further gains in sensitivity for HSE BOLD based functional imaging.

References: **1.** *Hyde et al 2001* **2.** *Krueger et al 2001*

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