fMRI Noise Correlation Revisited: The Role of Global Magnetic Flux Density Temporal Variations.

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INTRODUCTION: During single shot image acquisition steady state free precession (SSFP) can develop in the voxels under the condition T_2<TR (1). If residual transverse coherence is not properly spoiled and the global and non-linear field shift ($\Delta B_0(r,t) \cong \Delta B_0(t) + \gamma g(t) \Delta r$) is present, SSFP signal is disturbed and extra noise is induced in time series data. Global field shifts: $\Delta B_0(r,t)$ can be caused by system instabilities including eddy currents or physiological movements such as respiration (2). The SSFP disturbance-induced signal variation increases the fluctuations in the time series. These fluctuations can be coherent over time. We hypothesize that if physically separate voxels have similar and long (relative to TR) relaxation times, diffusion coefficients, inherent structure etc. it would be possible that the Functional Magnetic resonance (fMRI) time series will exhibit similar fluctuation structure. We have tested this hypothesis by conducting time series experiments on phantom.

MATERIAL and METHODS: The experiments were performed on a General Electric Horizon LX 8.3 scanner (3T/90cm) equipped with whole body gradient inset with maximum gradient amplitude 42 mT/m and slew rate 120 T/m/s. The "regional specific" phantom composed from four small plastic tubes (Figure 1A) was used. Bottom two tubes were filled with tap water (T_2=1.62s). Upper tubes were filled with $CuSO_4$ water solution (T_2=0.19 s). Single axial slice across the four tubes phantom was acquired. A gradient-recalled (GE) and a spin-echo (SE) single-shot echo-planar imaging (EPI) sequences were used for fast imaging. The crusher gradient amplitude was set to 20 mT/m. For manipulation with residual transverse coherence level two crusher duration lengths were used (short or unspoiled=1ms and long or spoiled=10 ms). The image parameters were TR 1s, TE 30 ms (GE) and 60 ms (SE), number of images 300, bandwidth ±65.5 kHz, FOV 16 cm, image matrix 64×64, slice thickness 6 mm, flip angle 90°.

RESULTS and DISCUSSION: Magnitude standard deviation images calculated from time series for unspoiled and spoiled GE and SE experiments are shown in Figure 2. It is evident that in both unspoiled GE and SE experiments noise level is elevated in both tubes with long T_2. System instability induced $\Delta B_0(t)$ shift can be roughly estimate from the time series of the phase images acquired in GE spoiled experiment. The standard deviation of the phase time course corresponds to ΔB_0 variation order of 2 nT. Correlation images from GE and SE-EPI resting experiments conducted on the "regional specific" phantom are presented in Figure 3. GE data with unspoiled (short crusher) echo contribution (Fig 3A) shows that time courses from bottom tubes (T_2~TR) are highly correlated. Because T_2* effect after spoiling echoes, still some correlation remains in GE data (Fig. 3C). SE data with short crusher (Fig. 3B) still shows some correlation due to SSFP disturbance. Because SE signal depends on T_2 after spoiling echoes no correlation remains (Fig 3D).

This study helps to address an important and unanswered question: What is physical origin of low frequency fluctuations observed in fMRI signal? It is assumed that these arise from correlated cerebral blood flow and oxygenation changes resulting from correlated and spontaneous "resting" neuronal activity (3). However because the possible anatomy and the T_2 similarities (mainly CSF contamination in the gyri) between functionally correlated regions, the effect of global field variation and possible SSFP disturbance should be also considered.

CONCLUSION: Evidence is presented that a weak (as low as 2nT) global system magnetic flux density variation can cause spurious noise correlations in fMRI time series data due to SSFP disturbance. Such noise correlation can be especially severe in voxels contaminated by cerebrospinal fluid (CSF) because of its long magnetic spin-spin relaxation time.

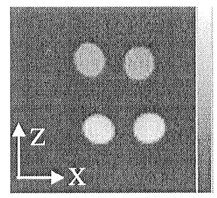

Figure 1.
The "regional" specific four's tube phantom. Bottom two tubes are filled with tap water (T_2=1.6 s), upper ones with $CuSO_4$ water solution (T_2=0.19 s).

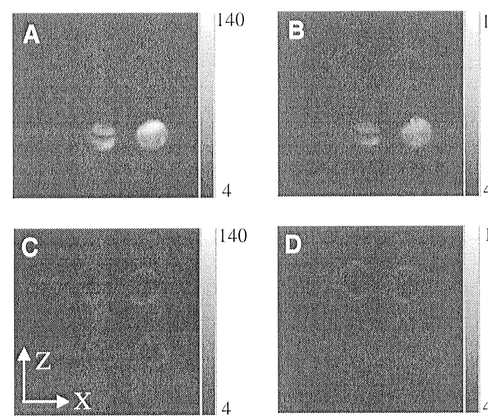

Figure 2.
Magnitude standard deviation images calculated from measured time series from: **(A)** GE unspoiled; **(B)** SE unspoiled; **(C)** GE spoiled and **(D)** SE spoiled experiments.

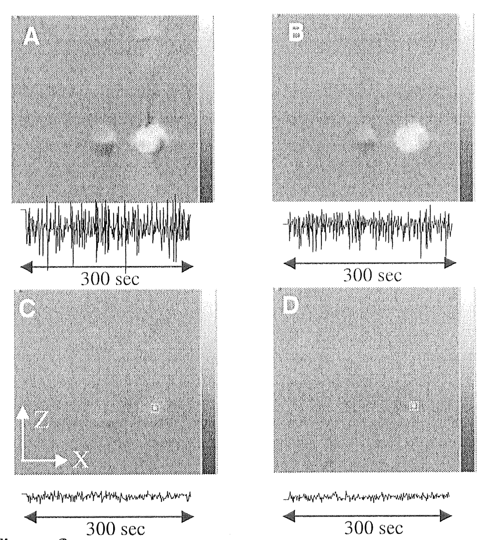

Figure 3.
Four tube phantom correlation images together with the normalized reference time courses calculated from: **(A)** GE unspoiled; **(B)** SE unspoiled; **(C)** GE spoiled and **(D)** SE spoiled experiments.

REFERENCES:

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