Background 0.1 Hz fluctuations are not in phase with post-stimulus oscillations in BOLD fMRI

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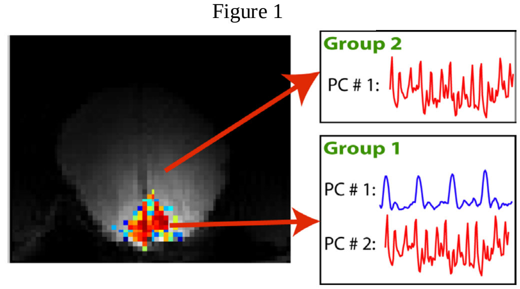
Introduction

Slow oscillations with frequencies around 0.1 Hz are widely observed in functional magnetic resonance imaging (fMRI) data acquired with blood oxygenation level dependent (BOLD) contrast [1,2]. Similar oscillations have been observed with optical techniques and in other parts of the body [1,3]. Although the mechanism of the oscillations is not completely understood, they are generally thought to reflect vasomotion. In preliminary investigations we have observed oscillations in the post-stimulus portion of the BOLD hemodynamic response to stimulus. The frequency of the oscillations is also around 0.1 Hz, and are consistent with a recent autoregulatory model of cerebral blood flow [4]. In this study, we examine whether the post-stimulus oscillations are in phase with the background vasomotion.

Methods

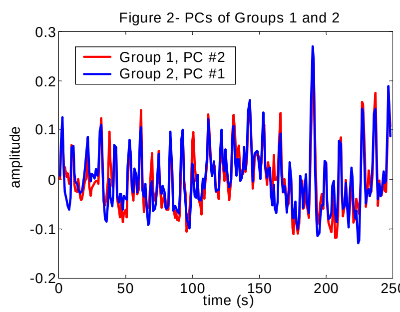
Imaging data were acquired on a Varian 4T whole-body system utilizing a single-surface coil placed proximal to the occipital lobe. A stimulus event was defined as a one second presentation of a 8Hz, full-field, maximal contrast, flickering checkerboard. Two experimental designs were utilized per subject and they consisted of a block design (4 periods of 20/40 seconds on/off) and a periodic design (8 events at 31 second intervals). Six 4mm oblique slices about the calcarine sulcus were imaged. Imaging parameters were FOV 24cm, 64x64 matrix, TE=27ms, flip $\theta=70^0$, and a TR=1 s. Respiratory motion was monitored with a respiratory effort transducer (BIOPAC). Average BOLD time series were formed by motion registering, detrending and averaging individual time-series over selected voxels and across runs. After correlation analysis with a reference function, the voxel time-series were binned into two groups. The groups represent regions of neuronal activation and regions of non-activation. Voxels with a correlation coefficient (CC) above 0.6 were placed in group 1, while voxels with a CC below 0.1 were placed in group 2. The selection process is schematically illustrated in Figure 1. The voxel time-series were then arranged in matrix M_1 for group 1 and matrix M_2 for group 2, with time as the row dimension. After subtraction of the mean from each voxel, a principal component analysis (PCA) was performed on the respective covariance matrix M^TM. As depicted in Figure 1. The first principal component (PC) of group #1 reflects the response to the stimulus pattern, while the second PC of group #1 and the first PC of group #2 reflect the presence of 0.1 Hz background oscillations.

Figure 1



Results

Figure 2 shows the overlay of the second PC from group 1 and the first PC from group 2 calculated from the periodic design runs. The components are highly correlated with a correlation coefficient of 0.9. Similar results were found obtained for the block design runs. The frequency spectra of the components are presented in Figure 3 and show a strong 0.1 Hz component. The measured respiratory frequency during the scanning session was 0.28 Hz. The cycle averaged stimulus responses for the periodic and block designs are shown in Figures 4 and 5, respectively. The frequency of oscillation in the post-stimulus response is about 0.1 Hz. In addition, for each of these runs, the first PC from group 2 was averaged over the cycles of the respective design. The cycle-averaged PCs are shown in Figures 4 and 5 and do not exhibit coherent structure.



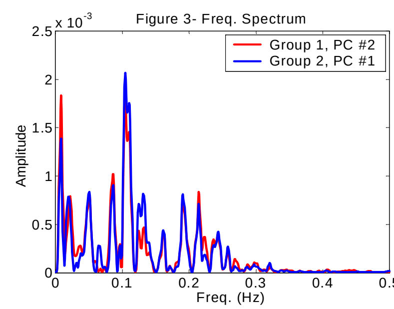


Figure 4

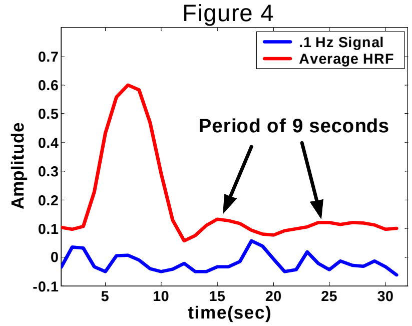
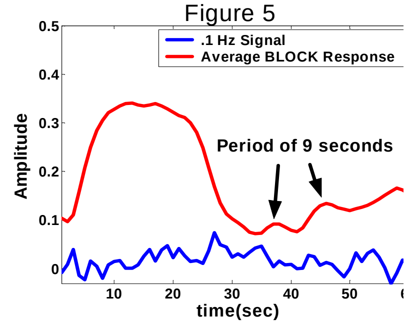


Figure 5



Discussion

The background 0.1 Hz oscillations in the activated and non-activated regions appear to be phase-locked and are not at the same frequency as respiration. Oscillations around 0.1 Hz were found in the post-stimulus responses for both periodic and block designs. The lack of coherence in the cycle-averaged background oscillations indicates that the post-stimulus oscillations are not in phase with the background vasomotion. In addition, this finding suggests that the stimulus does not reset the phase of the background vasomotion. Thus, the oscillatory response to stimulus appears to add linearly to the background vasomotion.

References:

[1] P.P. Mitra et al., MRM 37:511-518 (1997) [2] B. Biswal et al., MRM 34:537-541 (1995) [3] AG Hudetz et al., JCBFM 12:491-99 (1992). [4] KJ Friston et al NeuroImage 12:466-77 (2000)