Theoretical results demonstrate fundamental differences in venous BOLD reducing fMRI activation methods

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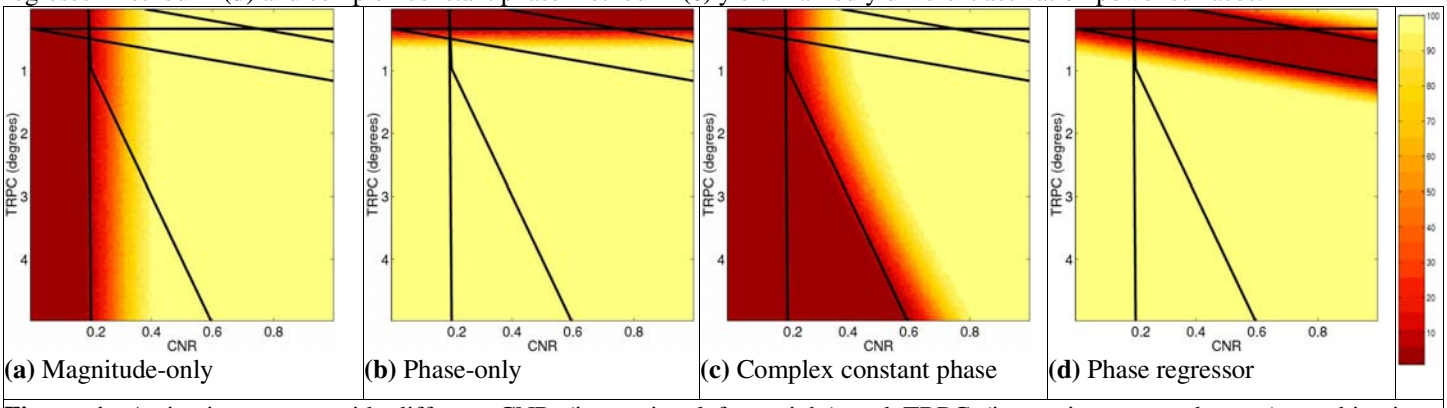
Introduction: As with all MRI, reconstructed images in fMRI are complex-valued as a result of imperfections in the Fourier encoding process. This complication is often surmounted by converting the complex-valued data into equivalent magnitude and phase data, then discarding the phase from further analysis [1]. Recent studies have shown that this phase data may contain physiologic information, including information about the vascular source of the BOLD signal [2]. It has been argued that activations which result from the microvasculature which is closely related to the region of cortical activation do not include task related phase changes (TRPCs), while activations which arise from delocalized draining veins include TRPCs. Further, recent advances in fMRI have aimed to utilize both the phase and magnitude data to compute cortical activations, biasing against declaring voxels with TRPCs from delocalized draining veins as active [2,3,4]. An optimal activation method would bias against voxels with TRPCs caused by delocalized draining veins but still be sensitive to task related magnitude changes (CNRs). It is the goal of this study to examine the characteristics of these methods when voxels contribute different combinations of TRPCs and CNRs.

Methods: Activation power was determined for the usual magnitude-only model [1], an analogous phase-only model, the phase regressor model by Menon [2], and the complex constant phase model by Rowe and Logan [3] with different TRPC and CNR combinations. Block designed time series were simulated over an array of 128 by 128 pixels with a SNR of 30. Over the array the CNR varied from 0 to 1 in the horizontal direction and the TRPC varied from 0 to 5 degrees in the vertical direction in 128 equal steps. The time course for each pixel was created utilizing the complex-valued general linear model [5]. The activation methods were used to determine pixels which would be declared active above a p=0.05, Bonferroni adjusted threshold [6]. The number of times that a pixel was declared active by each method over the course of 1,000 simulations was tabulated, and the activation power of each method for each pixel was defined to be the percentage of times that pixel was declared active.

Results: The results of the activation power simulations are included in the activation power surfaces in Figure 1. Note that the phase regressor method in **(d)** and complex constant phase method in **(c)** yield markedly different activation power surfaces.



(a) Magnitude-only **(b)** Phase-only **(c)** Complex constant phase **(d)** Phase regressor

Figure 1: Activation power with different CNR (increasing left to right) and TRPC (increasing top to bottom) combinations. Boundary lines added for comparisons.

Conclusion: When the TRPCs are small (<1°), the complex constant phase method **(c)** resembles the magnitude-only method **(a)**. Thus, it does not lose detection power in the region of CNR/TRPC combinations which are expected to be well localized to the microvasculature. When larger TRPCs are present, however, the complex constant phase method biases against pixels with small CNRs and large TRPCs. Therefore, it exhibits characteristics consistent with the ideal of biasing against draining veins. The phase regressor method **(d)**, however, resembles the phase-only method **(b)**, declaring all pixels with TRPCs active above a threshold of about a 1.5º. Thus, many pixels in the region of CNR/TRPC combinations that are expected to be caused by draining veins are declared active. However, with relatively small TRPCs and high CNR, the phase regressor method appears to bias against voxels with TRPCs, as seen with the small triangle of higher power in the upper right corner of the activation power surface in **(d)**. Thus, when only TRPCs of well less than 1º are present in data, the phase regressor method exhibits favorable behavior with low activation power, but does not when TRPCs are greater than 1.5º, as often is the case. Additionally, when the TRPC<.5º and CNR<.5 as would be for weak activation in the microvasculature, the phase regressor method yields lower detection power than the complex constant phase and magnitude-only models. In conclusion, the phase regressor method yields suboptimal results.

References: 1. Bandettini et al., MRM: 30, 161-173 (1993). **2.** Menon, MRM: 47, 1-9 (2002). **3.** Rowe and Logan, NIMG: 23, 1078-1092 (2004). **4.** Nencka and Rowe, Proc. ISMRM: 13, 495 (2005). **5.** Rowe, NIMG: 23, 1310-1324 (2005). **6.** Logan and Rowe, NIMG: 22, 95-108 (2005).

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