Complex Activation Suppresses Venous BOLD in GE-EPI FMRI Data

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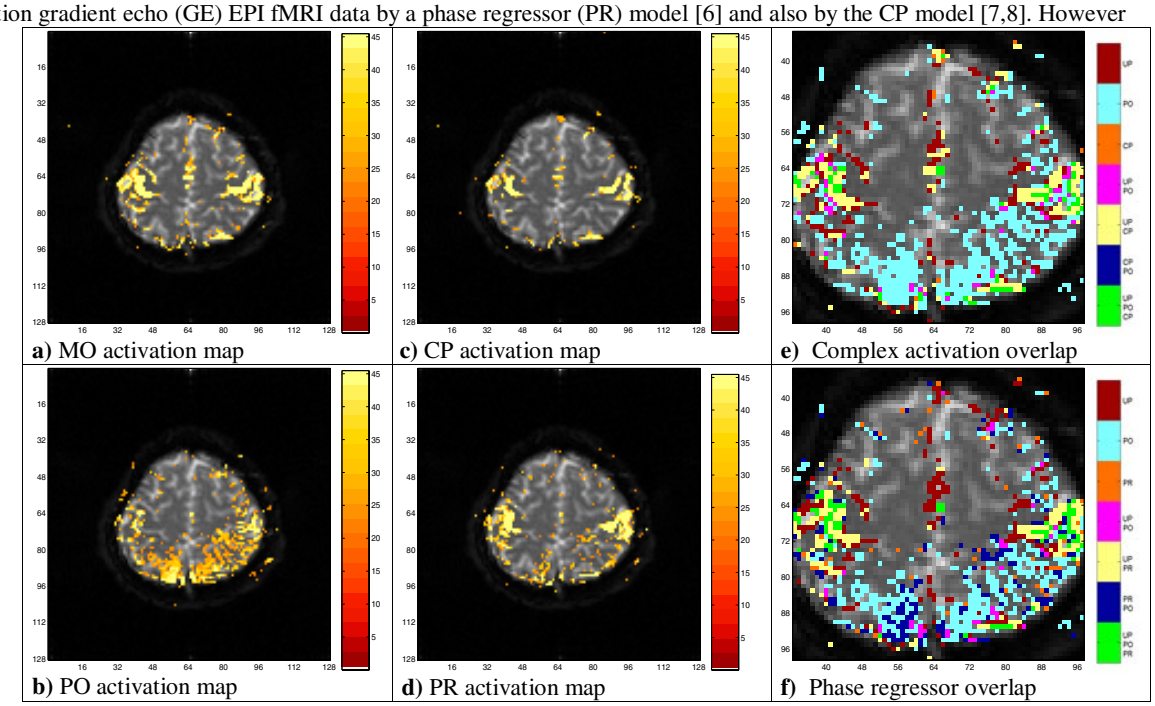
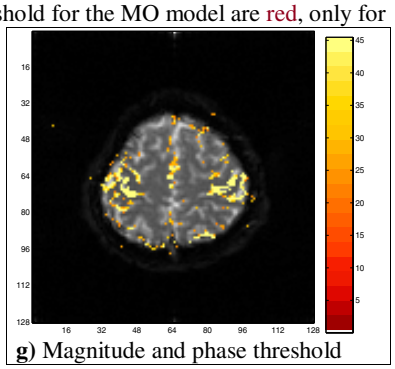
Introduction: In fMRI, voxel time courses are complex-valued after "image reconstruction." These real-imaginary time courses are converted to magnitude-phase time courses and the phase discarded. Recently it has been shown that there is useful temporal task-related phase change (TRPC) information in the phase regarding vascular "draining" vein effects. The phase can be used to suppress activation in undesirable voxels.

Models: Nearly all fMRI studies derive functional "activation" based on magnitude-only (MO) data time courses [1] after discarding phase time courses. A similar phase-only (PO) model can also be applied. Recently a magnitude activation from complex data with constant phase (CP) model was introduced that did not lose activation power as the SNR decreased [2]. It was also shown that the CP model accurately estimated the model parameters [3]. It was recently shown that the MO data model could be derived from complex data with an unrestricted phase (UP) [4]. The CP model was generalized to describe both the magnitude and phase [5]. Recently interest has arisen to suppress large-vessel BOLD signals postacquisition in high-resolution gradient echo (GE) EPI fMRI data by a phase regressor (PR) model [6] and also by the CP model [7,8]. However these two image analysis methods have not been examined together.

Example: Single subject data from a block-design sequential bilateral finger-tapping experiment with 16 s off then eight epochs of 16 s on and 16 s off. A 1.5 T GE Signa acquired single shot full *k*-space data with 5 axial slices acquired at 96×96, but reconstructed to 128×128. Voxels were in-plane 1.5625×1.5625 mm and 5 mm thick with TE = 47 ms, TR = 1 s and n = 272 observations taken. The first 3 images were deleted followed by low frequency and respiration filtering. A single slice was selected for analysis. The MO, PO, CP, and PR models were fit with an intercept, time trend, and ± 1 reference function that mimicked the experiments timing. Activation is from -2logλ likelihood ratio statistics and Bonferroni thresholded [9].



Results: In **a)** is the map from MO, **b)** PO, **c)** CP, and **d)** PR models. Note that the CP model appears the most localized to the parenchymal tissue in the central sulcus. In **e)** and **f)** are zoomed-in colored overlap maps where voxels that are only above the threshold for the MO model are red, only for the PO model light blue, only for the CP or PR model orange, for the MO and PO models pink, for the MO and CP models yellow, for the PO and CP or PR model blue, and for all three models green. There were no blue voxels in **e)**. It can be seen that the pink voxels in **e)** with TRPCs are below the threshold for the CP model. Note that the CP activation pattern is more localized than the MO or PR models. A closer inspection of the red voxels reveals that the majority of them also exhibit TRPCs but are below the Bonferroni threshold. It can be seen that the PR model in **f)** declares voxels active that are not active in the MO or CP models but are active in the PO model. It can be concluded that the CP model strongly biases against voxels with TRPCs which was verified by additional simulations not shown. It was also examined to see if the CP voxels in **c)** that are essentially a subset of the MO voxels in **a)** could be found by other means. Voxels that are active by the MO model in **a)** were eliminated if they were also active by the PO model in **b)** for a combined magnitude and phase (MP) threshold with map in **g)**. This map is similar but not identical to the CP map in **c)**. Note the active voxels in the left pre- and post-central sulcus. These voxels are just below threshold for the CP and the PO models.



Conclusion: The magnitude-only, phase-only, magnitude with a constant phase, and phase regressor models were applied to a real data set. Activation from the complex constant phase model were more focused compared to the magnitude-only and phase regressor models and concentrated on voxels without task-related phase changes as seen by its similarity to a map that eliminates voxels with above threshold phase-only activation.

References: 1. PM Bandettini et al., 1993. MRM. 30:161-173. **2.** DB Rowe and BR Logan, 2004. NIMG 23:1078-1092. **3.** DB Rowe, 2005. NIMG 25:1124-1132. **4.** DB Rowe and BR Logan, 2005. NIMG 24:603-606. **5.** DB Rowe, 2005. NIMG 25:1310-1324. **6.** RS Menon, 2002. MRM 47:1-9. **7.** DB Rowe, 2005. Proc. ISMRM, 13:1577. **8.** AS Nencka and DB Rowe, 2005. Proc. ISMRM 13:495. **9.** BR Logan and DB Rowe, 2004. NIMG 22:95-108.

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