Complex analysis of ASL fMRI data yields more focal activation

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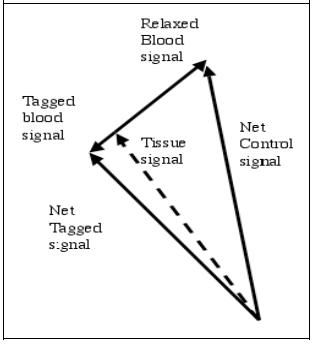
Abstract: Traditional analysis of fMRI data uses only the magnitude portion of the data. More recently complex analysis that uses both the magnitude and phase of the data has been developed for BOLD fMRI. The complex data approach is particularly pertinent for ASL fMRI analysis and has not been previously examined. We apply the new complex detection models to ASL fMRI data and find more focal activation than the magnitude-only approach. This complex data analysis has demonstrated its increased specificity for ASL data and the possibilities for more routine use.

Introduction: Typical analyses of ASL data are performed by estimating the parameters of a general linear model, using only the magnitude of the ASL images [1]. The image signal in MRI is complex in nature, but the phase information is routinely discarded in both medical imaging and functional imaging analyses.

Fig. 1: Signal Vectors in the control and in the tagged cases.



Rowe et al. [2,3] recently demonstrated that including the phase data increases the specificity of functional MRI analyses. This approach is particularly pertinent for ASL analyses. The magnetization signal arising from a given voxel is the sum of the tissue and the blood magnetization in the ASL experiment. In the control image, the blood magnetization is relaxed while in the tagged image, the blood magnetization arrives after experiencing inversion and relaxation. Spins moving in the microvasculature and in the presence of the imaging gradients acquire phase at a different rate than spins in the tissue. Thus, as Fig. 1 indicates, the *net* signal (after an imaging RF pulse) in the control and tagged cases have different phase as well as magnitude. The difference in phase and magnitude gets larger as blood flow and volume increase. In this work we examine the use of the complex GLM models for the analysis of ASL functional MRI time series.

Methods: Double coil Turbo CASL [1] images were collected during a bilateral finger tapping paradigm (20s rest, 10s active, 12 repetitions). Acquisition was carried out on a 3T MRI scanner (General Electric, Waukesha, WI). Acquisition was carried out using a spin-echo spiral imaging sequence (FOV = 24 cm, 3 slices, matrix = 64x64, slice thickness = 7 mm, Flow crusher b-value = 4 mm/s^2 , TE = 12 ms, TR = 1260 ms, Labeling time = 1000 ms). Labeling was carried out using a separate labeling RF system.

Analysis: Unsubtracted ASL data were first analyzed using GLS [4]. Here, unsubtracted data was also used. The design matrix had a column of ones for a baseline, a column of counting numbers for a linear trend, a column for the baseline ASL regressor, a column for the BOLD task regressor, and a column for the ASL task regressor of interest. The usual magnitude-only [1], an analogous phase-only (angular regression) [5], the complex constant phase [2], and complex magnitude/phase [3] activation models were applied.

Results: Activation maps thresholded [6] at the p=.01 level are presented in Figs. 2-5. Figs. 2-4 contain *z* statistics while Fig. 5 contains chi-square statistics with two degrees of freedom. Note the large task related magnitude detection regions in Fig 2. There is nearly no task related phase activation in Fig. 3 due to the spin-echo π refocusing pulse. Fig. 4 produces tight activation maps that are almost a subset of those in Fig. 2. In Fig. 5 is the activation map for detection of both magnitude and phase task related changes associated with the ASL task regressor of interest that is larger that that in Fig. 4 but still much more focal that that in Fig. 2. In the active voxels, the activation statistics remained above threshold in the complex analysis and more focally concentrated than the magnitude-only analysis.

Fig. 2: Magnitude-only.

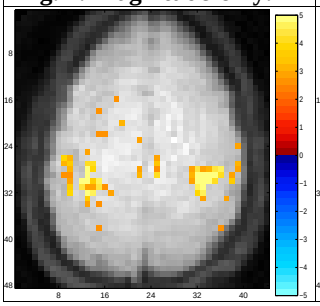


Fig. 3: Phase-only.

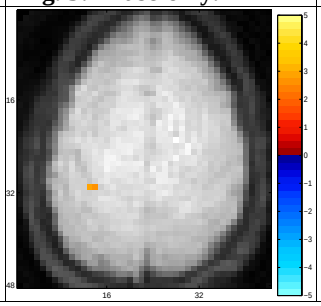


Fig. 4: Complex Constant phase.

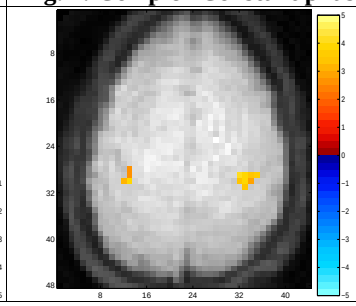
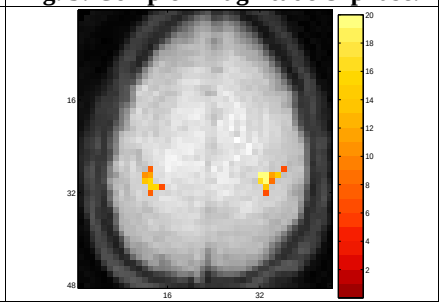


Fig. 5: Complex Magnitude & phase.



Discussion: As evidenced in these and previous published data, the complex analysis reduces false positives and yields more focal activation. This new method was shown to be more specific, since more information is used. However, the change in phase between control and tagged images is reduced as the arterial label decays past the null point. This analysis is likely to be more useful in acquisition schemes where the transit time is reduced.

References: 1. L Hernandez-Garcia et al., Magn Reson Med 51:577–585, 2004. **2.** DB Rowe & BR Logan, NeuroImage 23:1078-1092, 2004. **3.** DB Rowe, NeuroImage 25:1310-1324, 2005. **4.** JA Mumford et al., NeuroImage 33:106-114, 2006. **5.** DB Rowe et al., J Neurosci Methods, in press, 2006. **6.** BR Logan & DB Rowe, NeuroImage 22:95-108, 2004.