

Signal Processing Spreads a Voxel’s Temporal Frequency Task-Activated Peak and Induces Spatial Correlations in Dual-Task Complex-Valued fMRI

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**Background & Purpose:** To attenuate noise from image acquisition artifacts and unwanted physiological sources, inherent within the acquired signal, processing operations are applied before the statistical analysis of the data. It is well documented that processing operations modify a voxel’s temporal spectrum and induces correlation.<sup>1,2</sup> In this study, spatial correlations are described as a linear combination of second order voxel temporal frequencies using both the magnitude and phase components of the data.<sup>3</sup> The utility of this representation is established with a simulation of dual-task fMRI data. Given a dual-task experimental design with different task periods, two distinct task-activated peaks are expected. Signal processing will alter the activated voxel’s temporal frequency spectrums, by spreading voxel task activated peaks temporally and spatially into neighboring frequencies and voxels. If the frequency of the tasks falls within a close range, correlation will be induced between voxels activated by different tasks, as a result of increased overlapping frequency content. Without knowledge of the expected task-activated regions, it is difficult to resolve the task to the associated region after processing. This study contributes to the development of models to account for the impact of signal processing, with respect to the task-activated frequency, while preserving the signal of interest.

**Methods:** A Monte Carlo simulation is performed with 100 trials of a 96x96 Shepp-Logan phantom scaled to 100 in MATLAB with 720 repetitions and a TR = 1 s. The simulation is generated with a signal-to-noise-ratio (SNR) = 50 and contrast-to-noise-ratio (CNR) = 0.05, by adding normally distributed random noise with a mean = 0 and a standard deviation = 2 to the real and imaginary portions of the time-series, and an experimental block design with an amplitude of 1 is added, to four voxels of interest (VOIs),  $v_a$ ,  $v_b$ ,  $v_c$ , and  $v_d$ . The data is spatially smoothed with a FWHM = 3 voxels, band-pass filtered to analyze temporal frequencies in the range of 0.009-0.1 Hz. Note, the frequency range includes the simulated task-activated frequency peaks. To simulate a dual task experiment, and demonstrate three scenarios are considered. In each scenario,  $v_a$  is associated with task 1<sub>a</sub> performed for fifteen 24-second periods, *Scenario 1:*  $v_a$  vs.  $v_b$ ;  $v_b$  is adjacent to  $v_a$  associated with task 2<sub>b</sub> performed for eight 45-second periods, *Scenario 2:*  $v_a$  vs.  $v_c$ ;  $v_c$  is not within close proximity to  $v_a$  associated with task 2<sub>c</sub> performed for twelve 30-second periods, *Scenario 3:*  $v_a$  vs.  $v_d$ ;  $v_d$  is not within close proximity to  $v_a$  associated with task 2<sub>d</sub> performed for sixteen 22-second periods. The correlations between voxels are computed with the complex-valued (CV) temporal frequencies, and compared to magnitude only (MO).<sup>3</sup>

**Results & Discussion:** Fig. 1 is the before and after processing correlation maps for  $v_a$  showing magnitude MO and CV, and the values shown in Fig. 2 are the correlation contributions of the frequency point for each voxel. Note, the arrow color corresponds to voxel location defined in Fig. 2, and the sum of the correlation contributions for each voxel’s spectrum sums to 1. In scenario 1,  $v_a$  (black) and  $v_b$  (blue), demonstrates the impact of spatial smoothing on localized spatial correlation. Before smoothing  $v_a$  and  $v_b$  share no overlapping frequency content, thus, it is difficult to resolve the task with the associated specific region in a dual task-experiment. In scenario 2,  $v_a$  (black) and  $v_c$  (green), share no initial correlation, and are not within close proximity. Thus, no correlation is induced from the spatial smoothing, and the voxels have distinct activation peaks observed in Fig. 2. In scenario 3,  $v_a$  (black) and  $v_c$  (red) demonstrate the risk of a dual task-experiment with the tasks having periods that correspond to neighboring activation peaks in the temporal spectrum. These two voxels are not within close proximity to each other, the induced correlation between the two voxels is a result of the temporal frequency content spread to near by frequencies.

**Conclusion:** The closer the period of the two tasks, the higher the risk of false activation detection will be observed, after processing. The dual-task simulation substantiates the hypothesis that overlapping temporal frequency content leads to induced spatial correlations, which may have no task-based relationship. This study contributes to the development of regression methods to remove signal processing induced correlations, while retaining the signal of interest, to improve the accuracy and reliability of the results, with a potential application to multiband studies and data acquired at high field strengths.

**References:** 1.Friston et al., NeuroImage 2000. 2.Nencka et al., J. Neurosci. Meth. 2009. 3.Cordes et al., J. Am. NeuroRadiology 2000.

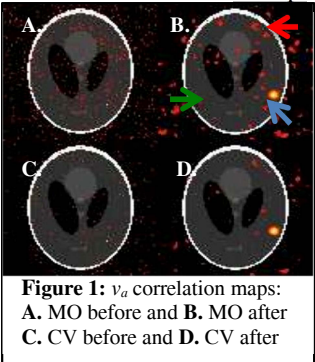


Figure 1:  $v_a$  correlation maps: A. MO before and B. MO after C. CV before and D. CV after

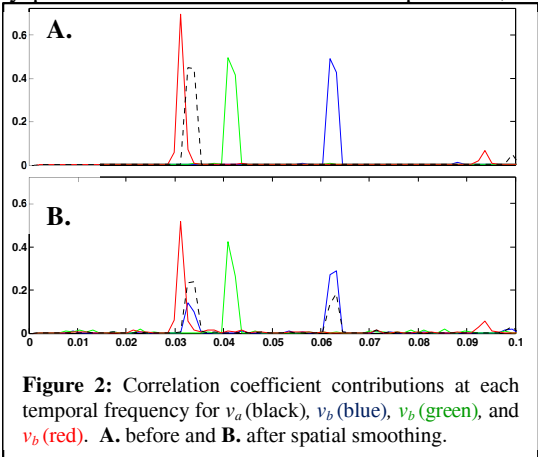


Figure 2: Correlation coefficient contributions at each temporal frequency for  $v_a$  (black),  $v_b$  (blue),  $v_c$  (green), and  $v_b$  (red). A. before and B. after spatial smoothing.

Table 1.	Corr( $v_a, v_b$ )	Corr( $v_a, v_c$ )	Corr( $v_a, v_d$ )
Before	0.0101	-0.0126	0.0217
After	0.8981	0.0766	0.1920