Movement Rate Modulation of Cortical Motor Systems Investigated with Partial Least Square Analysis

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Introduction

Task-related activity in cortical motor systems may be strongly influenced by the rate at which finger movements are executed. In previous studies we have used categorical contrasts and linear regression to identify brain regions exhibiting parametric sensitivity during voluntary movement [1]. Here we extend these observations by employing Partial Least Squares (PLS) [2,3] in the analysis of movements executed at various rates using either the dominant or non-dominant hand. The advantage of PLS is that it ignores any relation of elements within blocks of interest and only deals with the relations between blocks and is capable of investigating multiple contrasts in whole volume data. In this study, examination of the resulting latent variables (LV's), revealed multiple functional networks related to execution of finger movements at different rates.

Methods

Twelve right-handed subjects executed a button press in response to a visual stimulus appearing at three different frequencies: 0.3 Hz, 1 Hz, and 3 Hz. Both hands were used alternatively in different sessions. Multislice echo-planar image (EPI) acquisition was used (43 msec TE, 4.2 sec TR, 64x64 matrix, 230mm FOV, 46 axial slices, 3.6mm cubic voxels, 128 time points per run). The time series were processed using MEDx (Sensor Systems, Sterling, VA). To correct for within-run interscan head motion each EPI volume was registered to the mean of its time series using a linear 6 parameter rigid-body transformation model employing a least-squares cost function. Image volumes were resampled using scanline chirp-z interpolation. Global intensity variations were corrected with global image intensity rescaling, performed by computing the ratio that relates the mean image intensity in a particular volume to an arbitrary value of 1000. Low frequency temporal signal fluctuations were removed by application of a high-pass filter with a cutoff of twice the period length. Next, a 3D Gaussian filter (FWHM 6 mm in all dimensions) was applied to each volume in the time series. Images were then spatially normalized with a 3D warp to an EPI template in Talairach space. To reduce between run variability, task minus control difference images were generated for each movement rate and hand. For the PLS analysis, the task-related difference images from 12 subjects, at 3 different movement frequencies for each hand, were arranged in a 36 row matrix, with each row containing 30 slices. Two contrasts of interest were defined, to investigate sensitivity to parametric rate modulation. The product of the data matrix and the proposed contrast matrix was used to generate a cross correlation matrix. Singular value decomposition was applied to the cross correlation matrix, resulting in two non-trivial "so-called" latent variables, LV's, and their associated brain scores and design scores [2-3].

Results

The first LV revealed a cortical motor network that is different for slow tapping frequencies versus the average of high and middle frequencies. The first LV accounted for 94.45% of the total variance of the left hand data, and 95.73% of the total variance of the right hand data. The second LV identified modulation related to middle versus high frequency tapping, and accounted for only 5.55 % (L hand) and 4.27% (R hand) of additional variance. Overall, areas activated during left or right hand movement demonstrated expected lateralization of activity due to handedness. Modulation of these areas by changes in task performance corresponded well with previous work [1]. From the brain LV, more modulation for non-dominant hand task was shown. Areas showing task-related activity with either dominant or non-dominant movement included primary motor, primary somatosensory, cingulate and supplementary motor areas.

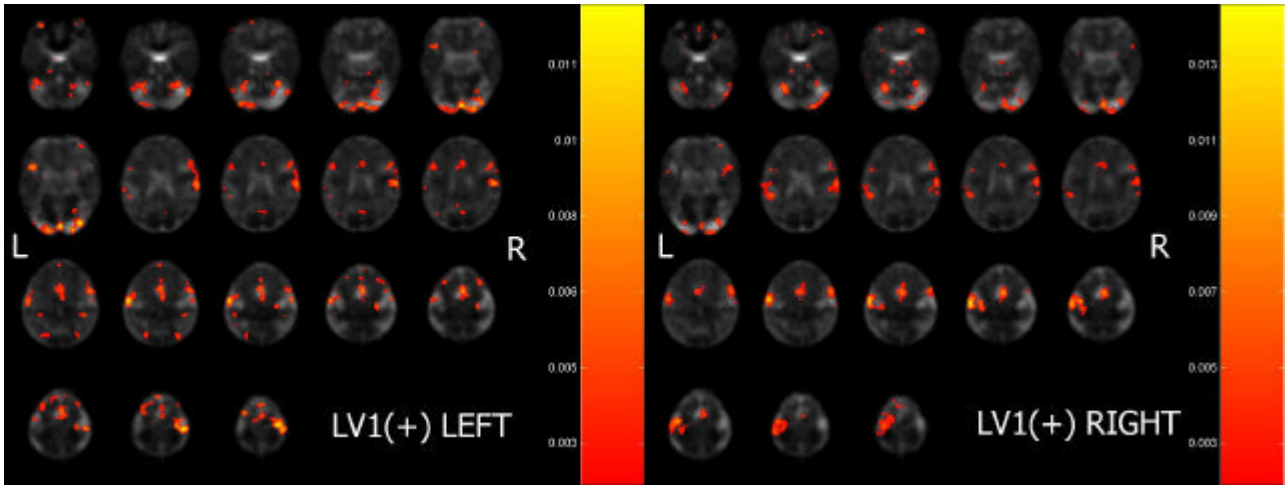

Fig. 1 The first positive LV for left and right hand movements. Only the most extreme 25% was shown on an arbitrary scale. This positive LV highlighted the difference of the average of middle (1 Hz) and high frequency (3Hz) tapping to slow (0.3 Hz) tapping.

Conclusion

Previous work has applied PLS to PET data [2,3]. Here, we demonstrate the feasibility of applying PLS to the analysis of fMRI data. The spatial-correlation from SVD in PLS identifies possible additional areas of task-related activity, which might be neglected by voxel-independent univariate estimation methods. The added sensitivity in PLS comes from the treatment of the image as a coherent multivariate system rather than independent voxel elements.

References

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