# Detection of Visual Attention using Partial Least Squares (PLS) Analysis of fMRI Data

Fa-Hsuan Lin[1,2], Anthony R McIntosh[3], Gary Strangman[4], Giorgio Bonmassar[1], Gregory V. Simpson[5] and John W. Belliveau[1],

*Massachusetts General Hospital NMR Center, Department of Radiology; Harvard-MIT Division of Health Sciences and Technology; Rotman Research Institute of Baycrest Centre, University of Toronto; Neural Systems Group, MGH; Albert Einstein College of Medicine, New York*

## Introduction

Detection and estimation of neuronal activity is an essential topic in brain mapping. Different analysis methods provide statistical inferences of the brain activity from different imaging/recording modalities. The prevailing univariate methods to analyze data, such as a t-test or Kolmogorov-Smirnov test (KS-test), have been successful in providing information of functional cerebral activation using different sensory stimuli.

Here, we applied a multivariate method called Partial Least Squares (PLS) to a visual attention fMRI experiment. PLS has proven to be a valuable multivariate analytic tool for positron emission tomography [1-3]. We evaluated the extension of PLS to fMRI data by comparing it with the outcomes of conventional univariate tests, including the t- and KS-tests. Single task PLS results show a comparable capability of brain activity detection by PLS and by conventional univariate statistical methods. Additionally, combined task PLS (incorporating multiple tasks/contrasts) reveals differences between passive, attend-left, and attend-right conditions, extracting the contrasts of interest directly from the data.

## Methods

Visual attention stimuli and fMRI image acquisition parameters are described in [4]. Two-sample t-test and non-parametric K-S were applied as univariate conventional activation detection schemes. The estimation maps of brain activation came from the p-value associated with the two different statistical methods.

PLS requires two matrices, data matrix, D, and contrast matrix, C, as inputs. Data matrix was formulated from each time point (T), X by Y voxels raw data to T*V matrix, where V=X*Y. Contrast matrix consists of proposed contrast vectors, each of which denotes a contrast of interest. Singular value decomposition was applied to the cross correlation matrix from D and C. This gives the brain latent variable, the design latent variable and the singular value.

PLS data matrix was pre-processed by voxel-wise temporal detrending and mean subtraction. Three orthonormal task contrasts (passive, attend-left, attend-right), and one paradigm contrast encoding on-off visual stimuli were used. Interactions between task contrasts and paradigm contrast were also included. A single-task contrast matrix was used to compare the three methods. The combined task contrast matrix was then applied to investigate the interaction of the proposed contrasts and correlate changes in brain activity with subject behavior.

## Results

Conventional t-test and KS-test were implemented to estimate brain activation in three tasks compared to a fixation baseline. Figure 1 shows the passive condition. The visual cortex was mainly activated. Sustained attention to the right hemifield results in greater activation in the cingulate cortex and frontal lobes, which is depicted in Figure 2.

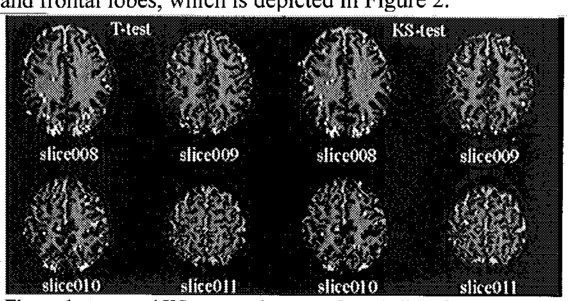


**Figure 1.** t-test and KS-test p-value maps from 4 slices for passive condition; white spots indicate p<0.001

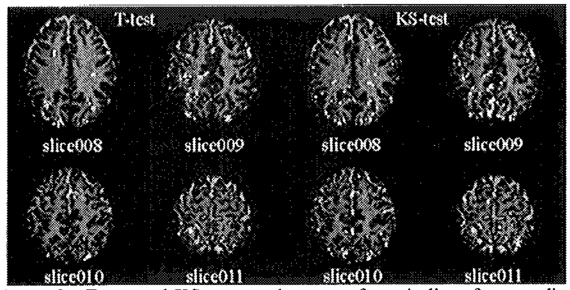


**Figure 2.** T-test and KS-test p-value maps from 4 slices for attending-right condition; white spots indicate p<0.001

In Figure 3, single task PLS shows the same visual cortex activation in the passive condition as in Figure1. Attention modulates fusiform region activity - greater brain activation contralateral to attended field. This pattern is consistent with t-test and KS-test results.

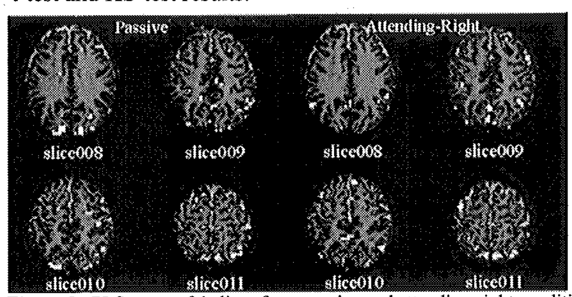


**Figure 3.** PLS maps of 4 slices from passive and attending-right condition; white spots indicate more than 0.5 maximal brain latent variable.

Combined PLS including three tasks revealed the weighted attention-passive, on-off, and left-right brain latent variables respectively, as shown at Figure 4.

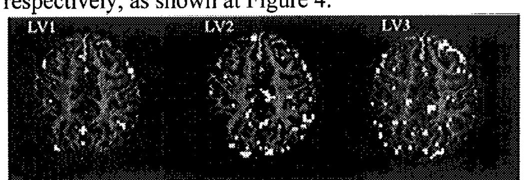


**Figure 4.** PLS maps of3 brain latent variable from slice009; white spots indicate more than 0.58 maximal brain latent variable.

## Discussion

We demonstrate similar brain activation patterns predicted by t-test, KS-test and single task PLS. This verifies the feasibility of applying PLS to fMRI time-series data analysis. Furthermore, the spatial-correlation from SVD in PLS pulls out possible extra voxel activation, 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. Combined contrast PLS reveals the possible brain regions for weighted attention vs. passive and attending-left vs. attending-right contrasts.

*References*

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This research was supported by NIH, AHA and MRC.