Increased detection sensitivity in fMRI by adaptive filtering

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Introduction
In [1] a new method for detecting neural activity in fMRI was introduced. In this contribution, the new method which is based on canonical correlation analysis is shown to be a natural extension of established detection methods when the latter are seen from a correlation perspective. In addition, the increased sensitivity of the new method is demonstrated.

Methods
It is well known that the today’s most widely used techniques for detecting brain activity in fMRI, the t-test and the ordinary correlation analysis (OCA), are equivalent [2]. Perhaps less noticed is the equivalence between an F-test and a multiple correlation analysis (MCA). In an F-test and a MCA, the square-wave reference timecourse commonly used to model the blood oxygen dependent (BOLD) response is replaced by a set of basis functions, e.g. a truncated Fourier set. For each voxel, the linear combination of these basis functions which correlates the most with the voxel timecourse is found. One advantage with this method is that it is invariant to any time delay in the BOLD response. Figure 1 illustrates an OCA and a MCA where x(t) is a voxel timecourse and y(t) represent timecourses used to model the BOLD response.

![Fig. 1 Ordinary and multiple correlation analysis.](image)

Obviously, OCA is a special case of MCA with only one basis function. In the same manner we can generalize the MCA to a canonical correlation analysis (CCA) by introducing multidimensional variables on both sides, see Fig. 2.

![Fig. 2 Canonical correlation analysis.](image)

Instead of analyzing a single voxel at the time, the novel CCA detection method considers a region of voxels, in Fig. 2 exemplified with a 3x3 region. For each region, the CCA finds a linear combination of the voxel timecourses, i.e. a linear filter, which correlates the most with a linear combination of the basis functions. In the presence of a BOLD response in the voxel timecourses, the CCA will adaptively find a filter which extracts the response and reduces the noise. Simultaneously a linear combination of the basis functions is found which most adequately models the extracted BOLD response, i.e. yields maximum correlation with the CCA-filtered response. The linear combination coefficients are given in the vectors \( \mathbf{w}_x \) and \( \mathbf{w}_y \) respectively. The region is slided over the fMRI image to produce a map of sample canonical correlations.

Results
The timecourses in Fig. 3 illustrates an OCA of an activated voxel. The fMRI images have been spatially smoothed with a Gaussian filter prior to the analysis to enhance the signal to noise ratio. The correlation between these timecourses is 0.51. In Fig. 4, timecourses found by the CCA are shown. The smooth signal is the combination of sine/cosine functions in the Fourier set which is found to model the BOLD response most adequately. The rough signal shows the voxel timecourse which is the result from the adaptive filter that the CCA found for the current 3x3 region. The correlation between these timecourses is 0.72. The correlation between the CCA-filtered voxel timecourse and the square-wave in Fig. 3 is 0.63. Hence, by adaptively filtering the region, the sensitivity is increased also when the square-wave is used to model the BOLD response, compared to the OCA.

![Fig. 3 An ordinary correlation analysis between a square-wave model of the BOLD response and a spatially Gaussian filtered voxel timecourse.](image)

![Fig. 4 The CCA-filtered voxel timecourse and the model timecourse for the BOLD response.](image)

Conclusion
We have illustrated how adaptive filtering is obtained by using a detection method based on canonical correlation analysis. The increased detection sensitivity compared to spatially filtering the fMRI images with a fixed Gaussian filter was also demonstrated.

References
[1] O. Friman et. al.
Detection of neural activity in fMRI using canonical correlation analysis. MRM, in press.