Determination of the Variability of fMRI Responses Using Deconvolution Analysis

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Introduction

A large number of statistical tests (including t-test, cross-correlation, F-test, deconvolution, etc.) are currently used in functional Magnetic Resonance Imaging (fMRI) to localize and quantify task-induced signal changes. It is currently assumed that fMRI time-points are stationary i.e., signal characteristics do not change over time. In this study, time-varying signal characteristics of fMRI signal response were investigated using Impulse response function. Substantial variation in the activation map was obtained for bilateral finger tapping paradigm. The proposed method can be extended to study variation between different experiments, and can also be used to detect habituations, or learning effects.

Method

To test the variability in a scan bilateral finger tapping was performed. Four healthy volunteers (3 M, 1F) were scanned after written informed consent was obtained. This study was approved by the IRB at this institution. Images were obtained using a 3T Siemens Allegra imaging system. Single shot gradient echo (GE) axial EPI images (64×64, TR=1s, TE=27 ms, FOV= 22cm x 22 cm, slice thickness = 5 mm, 17 slices) were acquired over 1024 data points. The scan was obtained while subjects were instructed to perform bilateral finger tapping in a random fashion. Both the ON and the OFF periods during the entire run varied at random. Because the hemodynamic response is sluggish in nature and takes about 6-8 seconds before the fMRI signal increases over baseline, the randomized stimulus had a minimum of 8 seconds both for the ON and the OFF period. The maximum period the stimulus was ON or OFF was for 12 seconds. The stimulus was designed as a boxcar where both the ON and OFF time were randomized. The same random GO/STOP sequence was used for all the subjects.

Data Analysis

Deconvolution analysis was used to estimate the impulse response function (IRF) on a voxel-by-voxel basis. In deconvolution analysis, however, the assumption is much less stringent and can accommodate for more complex input/output relationships. In Deconvolution, the assumption is that the response is a sum of scaled and time-lagged versions of the input. To analyze the time varying signal characteristics during task activation, the original data set (consisting of 1024 points) was broken into smaller intervals and both correlation and deconvolution analysis was performed for each block separately. Analysis was done for the entire brain on a voxel-by-voxel basis. In this study, three different interval sizes (of 256, 128, and 64 sequential time-points) were used. Although a smaller window size could have been used, in this study a window size of 64 sequential time points (64 seconds) was found to the smallest size that gave reliable results. To obtain a sequential update about the estimation of the IRF on a voxel-wise basis, the time-series data sets was incremented by fixed numbers. In this study, the initial (first) and the final (last) time-points used in the deconvolution and correlation analysis were increased by 50 time-points (50 seconds) and the impulse response recalculated for each block. Once the IRF has been estimated, convolving the input stimulus with the IRF would result in the predicted output response.

Results

Significant amount of variation, both in the number of pixels that passed the threshold (of 0.35) and the mean correlation coefficient in the sensorimotor cortex was observed in all the subjects. Figure 1 shows that activation maps generated from a representative subject during various blocks. In the 1st block a significant reduction was observed. While this may be due to fatigue (the scan being more than 17 minutes), this method provides a way for quantifying time-varying changes. Figure 2 shows IRFof blocks that had highest and lowest correlation with the ideal waveform from a certain pixel in the sensorimotor cortex, again showing time varying distinction.

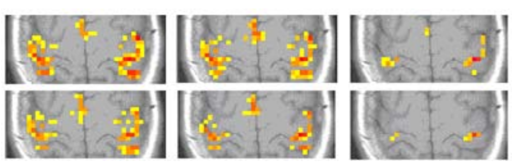

Figure 1**: Variability in activation within one scan.**

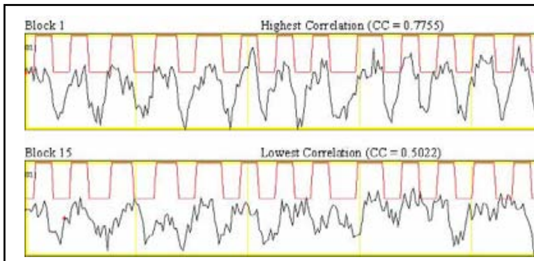

Figure 2**: Impulse Response Functions of Subject #1**

Discussion

This study demonstrates the use of Deconvolution analysis to study the variability of fMRI response on a voxel-wise basis. Variability between voxels was found to significant even for a simple bilateral finger tapping paradigm. The variability in a voxel was also found to be to vary across pixels suggesting it was not due to some global effects like head motion, respiration. Because there exists variability in the time-points that vary from voxel to voxel the sources of variability appears to depend on the underlying neuronal/vascular effects.