Detection of neuronal activity induced response from task-induced fMRI response using breath hold

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INTRODUCTION

Task-induced fMRI signal changes can be considered as neuronal activation convolved with intrinsic hemodynamic changes. As a result, it is not possible to account for any intrinsic hemodynamic changes that affect signal detection. To overcome this problem, various groups have obtained the averaged task–induced impulse response during a particular task (from a specified region) and convolved it with the input stimulus from a different task and used this as a reference waveform. In this paper, a voxel-by-voxel estimate of the intrinsic hemodynamic transfer function (iHRF) was obtained during breath holding, which is predominantly a hemodynamic response with negligible neuronal activity and metabolic consumption. The iHRF obtained during breath hold was convolved with the idealized reference for the finger-tapping task to generate reference waveforms on a voxel-by-voxel basis. These reference waveforms were then correlated with their corresponding fMRI signal responses.

METHODS

Five (4 males, 1 female) healthy volunteers aged between 22-30 years were chosen for this study. All subjects were recruited from a University setting and gave informed consent for the study. All images were obtained using a dedicated head-only 3.0 T Magnetom Allegra (Siemens) scanner retrofitted with a custom-made radio-frequency coil. All protocols used in this study were approved by the local IRB. Image acquisition started with a high-resolution anatomical scan. Based upon the anatomical images, typically 20 single-shot axial EPI slices (5 mm thickness) covering most of the cortex were obtained. Images were acquired using a 64X64 matrix with a TR=2sec, TE=30msec and an FOV=24cm. Subjects were scanned under three conditions (1) rest while breathing room air, (2) bilateral finger tapping while breathing room air and (3) rest during apnea (breath hold).

The intrinsic hemodynamic response function (iHRF) was calculated on a voxel-by-voxel basis (from the breath hold time-series) using a deconvolution method (Glover, 1998). The iHRF from each voxel was then convolved with the idealized boxcar reference waveform to obtain a smoothed response waveform that had taken into account the changes due to intrinsic hemodynamic response. Because, temporal delays for breath hold and finger tapping were ~ 26 and 8 seconds respectively, all responses were shifted by ~ 20 seconds. Activation of pixels was determined using a correlation with a boxcar reference function and a threshold of 0.5 for the correlation coefficient.

RESULTS

Significant changes due to breath hold were observed in the gray matter. The estimated iHRF was able to detect both the amplitude and shape representing the response. In regions that did not respond to breathing (for example white matter regions), response consisted of small magnitude random noise. The idealized boxcar waveform was then convolved with every iHRF and thus a unique waveform that took into account the underlying hemodynamic response was estimated. Each voxel waveform was then correlated to the task induced fMRI signal response with its

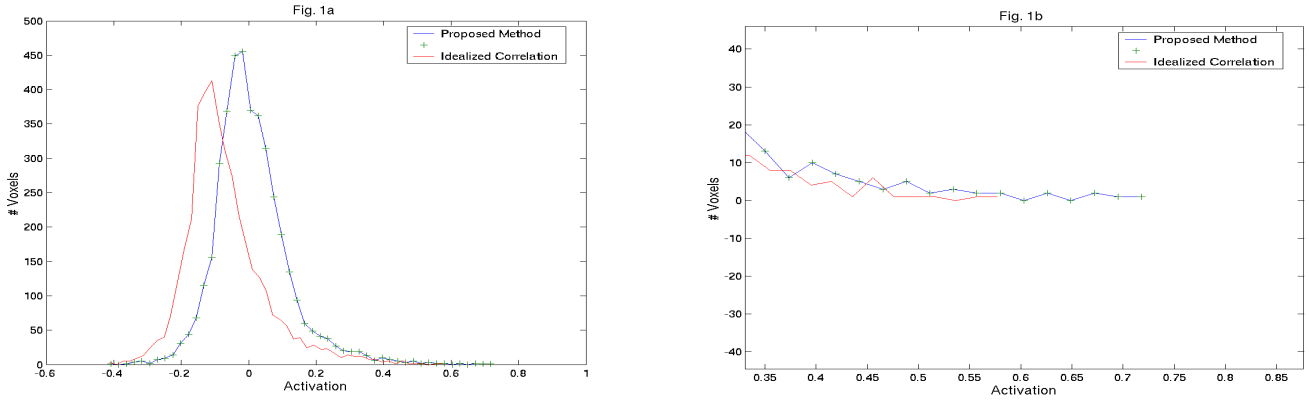

Fig. 1. Correlation coefficients for a single subject obtained using the proposed method and the idealized boxcar reference waveform. (a) Activation data using the proposed method and idealized reference. (b) At a threshold of .5, the proposed method shows a greater number of activated voxels.

corresponding voxel. A histogram of those correlation coefficients along with correlation coefficients obtained using an idealized boxcar reference waveform is shown (Fig. 1). In 4 out of 5 cases a greater number of voxels passed the threshold of 0.5 using the proposed method. Further analysis showed that in the proposed method activated voxels were found to be clustered around sensory-motor cortex.

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CONCLUSION

In this study, a method for detecting neuronal activity induced changes from task-induced fMRI response using breath hold is presented. In addition this method gives an estimate of the iHRF on a voxel-by-voxel basis for the entire cortex. By using a voxel-by-voxel comparison, differences in task activation changes that could solely be due to neuronal changes can be detected.

Glover, G. H. 1998. Deconvolution of Impulse Response in Event-Related BOLD fMRI. NeoroImage. **9**: 416-429.