Spatiotemporally coordinated activation detected during apparent rest in fMRI

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Introduction

Studies have shown that when apparently at rest the brain remains active, and is organized into functional networks that exhibit recurring patterns of activity [1-3]. Here, by exploring time series data at 7T using Wiener deconvolution in combination with a temporal T-statistic [4], we find individual spatiotemporally coordinated activation events during apparent rest, in no particular recurring pattern, but consistent with individual mental tasks or individual small movements of the body.

Methods

Five subjects were scanned at 7T Philips scanner using a 16-channel head coil (Nova Medical, MA). Two datasets were acquired per subject using a single-shot EPI sequence with 2^3 mm^3 isotropic resolution, SENSE factor: 1.5 and with the following parameters: Dataset1) TR=2s, TE=30ms, flip=80^0, 342 time points, and Dataset2) TR=400ms, TE=30ms, flip=40^0, 1710 time points. 20 and 6 oblique slices were acquired respectively, including regions in the superior frontal and occipital cortices. Run duration was 11.4 min during which subjects performed the following (Figure 1A- EMG trace): 140s rest; 4s of cued finger tapping; 196s rest; 300s during which subjects performed 2 cycles of 4s of finger tapping at will (uncued). During rest subjects were asked to visually fixate on a cross. EMG measurements were acquired for all subjects for both hands (left/right extensor, right flexor). A high resolution anatomical T2*w scan was also acquired ($1mm^3$, 3D segmented FLASH). Data were motion corrected and further processed using AFNI (NIMH/NIH) and in-house developed algorithms. A temporal T-statistic was computed for each voxel and time point using Wiener deconvolution with a dual-gamma-variate, canonical hemodynamic response function [4]. T-statistics were FDR-corrected considering all time points and voxels. A particular voxel/time point was declared 'active' if the temporal T-statistic exceeded the threshold set at an FDR corrected two-sided p-value=$1e^{-5}$. The result of the analysis was time course maps, showing the time course per voxel consisting of the T-values if above threshold, or zero if below threshold (Fig. 1 A-F). Plots of the sum of the T-statistic across image slices against time were made (T-plots, Figure 1A). Peaks in this plot indicated time points when activation was occurring in multiple voxels simultaneously. Results were validated by analyzing the original time series data using the first time point of each non-zero value in the thresholded temporal T-statistic time course as a stimulus onset for conventional regression.

Results

Activations associated with the cued and uncued finger taps (confirmed by the EMG measurements) were detected for all subjects (Fig. 1E). However spatio-temporally coordinated activation events relating to hand, face, or body movement were also detected during the rest periods for all subjects, and also confirmed with the EMG measurements, and engaged similar cortical areas for all subjects, e.g. SMA, motor, and somatosensory areas (Fig. 1D). Furthermore similar coordinated patterns of activation not directly related to movement were also detected for all subjects. These did not show a specific recurring pattern per subject or a consistent spatial/temporal pattern between subjects, suggesting they were likely related to individual mental tasks (Fig. 1B, C). Similar results were obtained for both TRs, and from the conventional regression analysis. Fig. 1F shows a control area where no peak was detected in the T-plots.

Discussion

Results show that spontaneous movements with no recurring pattern can alter resting state fMRI signals. Furthermore the subject may perform other mental tasks that cause non periodic, coordinated activation across the cortex. Patterns presented here may relate to attention [5] or somatic perception [6] (Fig. 1B, C). Even though the functional significance has not been elucidated, their presence indicates that there is more information in the apparent rest periods than may be observed using correlation analysis or ICA. These spontaneous events can reduce sensitivity in standard fMRI analysis and are an additional consideration for resting state analysis.

References: [1] Biswal et al., MRM 34:537-541, 1995; [2] Gusnard et al. Nature Reviews 2:685-694, 2001; [3] De Luca et al, NeuroImage 29: 1359–67, 2006, [4] Caballero et al, ISMRM Proc 2008, p.3623. [5] Pessoa et al. J. Neurosci. 23(10):3990–8, 2003; [6] Felician et al. Clin. Neurophysiology 38:183-187, 2008.

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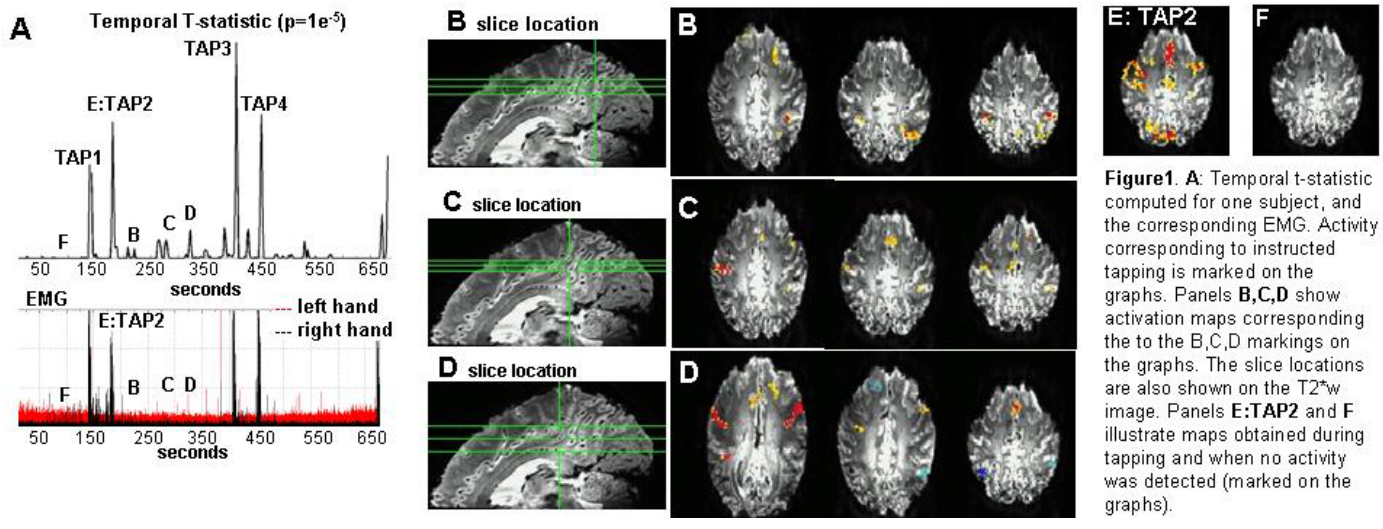

Figure1. **A**: Temporal t-statistic computed for one subject, and the corresponding EMG. Activity corresponding to instructed tapping is marked on the graphs. Panels **B,C,D** show activation maps corresponding the to the B,C,D markings on the graphs. The slice locations are also shown on the T2*w image. Panels **E:TAP2** and **F** illustrate maps obtained during tapping and when no activity was detected (marked on the graphs).