Localized Parallel Echo Volume Imaging at 1.5 T: a first extensive fMRI study

C. Rabrait[1], P. Ciuciu[1], A. Ribés[1], C. Poupon[1,2], P. Le Roux[3], D. Le Bihan[1,2], and F. Lethimonnier[1,2]

[1]Service Hospitalier Frédéric Joliot, CEA, Orsay, France, [2]Neurospin, CEA, Gif sur Yvette, France, [3]Health Care, General Electric, Buc, France

Introduction

With event-related fMRI (1), it has become possible to investigate the temporal features of complex cognitive mechanisms (2,3,4). To date, due to the poor temporal resolution of fMRI acquisitions, these studies mostly rely on the correlation of measured temporal parameters of the hemodynamic response function (HRF) to behavioral data. Using well-designed stimulation paradigms and modeling tools, it is even possible to separate different tasks at a temporal resolution well below TR (5). To push the temporal resolution limits of fMRI even further, we have developed a single shot 3D BOLD acquisition (Echo Volume Imaging, EVI) which gives a temporal resolution of 225 ms in localized brain volumes. Such a high temporal resolution is made possible by reducing the field of view (outer volume suppression pulses, OVS) along the phase and partition directions, and using a 2D parallel acquisition (SENSE reconstruction) with a reduction factor (up to 4) (6-8). We report here the first extensive fMRI study performed with this method and provide elements of comparison with a conventional EPI acquisition.

Methods

Experiments were performed on a 1,5 T GEHC scanner (40 mT/m, 150T/m/s slew rate gradient, 8 channel head coil array) on five healthy subjects. The MR sequence and reconstructors were implemented using the NMR package (9). Two sessions of a slow visual event-related paradigm were acquired for each subject using EVI, and one session was acquired using a conventional EPI acquisition with the same spatial resolution for two subjects. The stimulus was a black and white contrast reversing checkerboard with a 20-ms period which appears during 80 ms, followed by a 24.67-ms rest period (ISI = 24.75 s). One session consisted of 20 runs of the stimulus. Only EPI time series were corrected for slice timing, then all series were corrected for subject motion with SPM2 (www.fil.ion.ucl.ac.uk) and high pass filtered. No spatial smoothing was performed. Response magnitudes for each voxel were estimated using a general linear model with a canonical HRF and its first derivative as regressors. A Fisher (F) test was performed to assess significance. 3D views and superimpositions with anatomical data were performed using Brainvisa and Anatomist (http://brainvisa.info). Single-voxel HRF were recovered from the raw time courses extracted from the corrected data of activated voxels. These temporal data were first corrected from low-frequency drifts, then smoothed using a temporal gaussian kernel (σ = 1.0 s) and finally, averaged over the repetitions of the stimulus. No global scaling was performed.

EVI acquisitions: sagittal plane (SP), TE/TR = 40/225ms, flip angle (FA) = 35°, BW = 62.5kHz, FOV = 80x80x100mm^3, acquisition matrix 20x10x10 (reconstructed to 20x20x20), echo train duration (ETD) = 60.5ms. **Sensitivity maps:** SP, TE/TR = 10/500ms, FA = 30°, BW = 62.5kHz, FOV = 240x240x100mm^3, matrix 60x60x20. **EPI acquisition:** SP, interleaved acquisition, TE/TR = 40/1650ms, FA = 90°, BW = 125.0kHz, FOV = 240x240x100mm^3, matrix 60x60x20, ETD = 40ms.

Results

The principal results are summed up in Table 1. First, the number of tested voxels (with mean MR signal greater than 10% of the maximum) were very close in all EVI sessions (3273+/-132 voxels). Hence, the manual positioning of the acquired volume on the visual cortex was quite reproducible. EPI volumes were cropped before post-processing to match EVI ones. Nevertheless, the number of tested voxels was still greater for EPI volumes, since there was no signal in the edge slices of the EVI volume in order to avoid aliasing along the partition direction. Second, activated voxels with a high level of significance were detected for all subjects and sessions. Moreover, on superimpositions of F-maps obtained with both EVI and EPI to anatomical data, activated voxels were found mostly located in the grey matter. Fig.1 displays the comparison of spatial distribution of the activations detected in EPI and in EVI. On these two maps, the smaller extent of the clusters detected in EVI and small differences in localization appear. Third, the HRF could be computed for all activated voxels and the shape of the curves in EVI sessions were in good agreement with the canonical hemodynamic response expected. Thus, dynamic features such as the time to peak and width of the HRF, could be straightforwardly derived. These values presented no strong differences between EVI and EPI. The percent signal changes (ΔS_{BOLD}) averaged for activated voxels (thresholded at p<0.001) in each session are summed up in Table 1. EVI sessions gave a ΔS_{BOLD} higher than the EPI session (average 1.92 % ± 0.38 vs 0.84 % ± 0.07). Besides, the values measured with the EPI session were in good accordance to the values measured in the litterature for slow event-related visual experiments with short stimulus durations (10).

	Subject 1		*Subject 2*		*Subject 3*		*Subject 4*			*Subject 5*		
	run 1	*run 2*	*run 1*	*run 2*	*run 1*	*run 2*	*run 1*	*run 2*	*epi*	*run1*	*run 2*	*epi*
Tested vox.	3232	3331	3030	3359	3415	3447	3128	3417	5600	3149	3218	6081
Activated vox. (p<0.005)	39	92	215	250	176	279	100	43	269	46	47	669
Activated vox. (p<0.001)	13	52	142	170	88	164	48	17	168	32	28	496
ΔS_{BOLD}	1.7	2.6	2.1	1.6	2.1	2.0	2.1	1.9	0.9	2.0	1.2	0.8

Table 1. fMRI results for all EVI and EPI runs. F-tests non corrected for multiple comparisons.

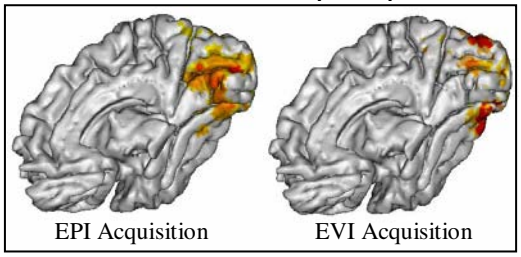

Figure 1. Comparison of the spatial distributions of cortex activations detected with EVI and EPI (subject 4, right cortex). Right: F-maps obtained for the EPI run (thresholded at F > 5.40, p < 0.005). Left: superimposition of the two F-maps obtained for EVI runs (thresholded at F > 4.60, p < 0.01).

Discussion

The smaller extent of the activated areas and the higher ΔS_{BOLD} measured in EVI lead us to investigate more precisely the nature of the BOLD signal we detected. By construction, SNR was lower with our EVI sequence than with EPI, and the smaller number of activated voxels with EVI could result from a lower sensitivity. Furthermore, artifactual activations have been detected at 1.5T with EPI from through slices inflow effects (10). Such artifacts can be reduced using 3D imaging, low excitation flip angle and application of OVS pulses parallel to the slice (11). Thus, the combined effect of inflow artifacts reduction and different T1 weightings in EVI could result in a better specifity and a better sensitivity to detect true BOLD effects. Activation-induced T1 variations in brain tissues cannot be ruled out at this stage (12) and subject to further investigation. Moreover, the extension of the acquired volume to a larger volume of the brain is in progress to accommodate more complex fMRI paradigms.

References:

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