EEG recordings and Spin-Echo Magnetic Resonance Imaging of visual evoked responses

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Purpose

The aim of this work is to supply experimental evidence for the detection of visual evoked responses by Spin-Echo Magnetic Resonance Imaging (SE-MRI).

Background

Recent works have investigated the feasibility to detect primary magnetic effects induced by neuronal currents during brain activity by MRI [1-4]. Discordant results were found with regard to the MRI detection of both neuronal spontaneous activity (SA) and evoked responses (ER), the two facets of cerebral activity mostly studied by EEG-MEG methodologies. Although spontaneous rhythms have greater amplitudes, evoked responses (ER) have two main advantages: first, they have a precise latency with respect to the event, measurable by EEG-MEG; second, they can be better localised, by EEG-MEG and BOLD fMRI. Both features together enable the use of repetition times close to that commonly used in BOLD fMRI, without compromising the SNR, and the detection of more than one slice positioned in the locus of activation.

Methods

The work was approved by the local ethics authorities. Three healthy subjects (1f,2m, age 27+-2yrs) participated in the study, after written informed consent. The visual stimuli consisted of a wind-mill checkerboard, lasting for 50 ms. ER potentials (ERPs) were recorded by a 64 channels EEG apparatus, before MRI scanning. The stimulus was presented 800 times. EEG-responses time-locked to the stimulus were extracted by signal averaging and dipole orientation, position and intensity were estimated by the BESA software. During MRI scanning (1.5T Magnetom Vision, Siemens medical systems, Erlangen) the following protocol was performed, using the same visual stimuli: 1) 96 BOLD-sensitive gradient-echo (GE) EPI magnitude images (TR = 3s, TE = 64ms, 16 slices, mtrx=64x64, FOV=192, slice thickness = 5 mm, stim. at 6.7Hz, 10 scans on/off cycle) in order to localise the stimulus induced hemodynamic responses; 2) 384 SE magnitude and phase images (TR = 1.3s, TE = 100ms, 4 slices, mtrx=64x64, FOV=192, slice thickness = 5 mm, stim. at 2Hz, 10 scans on/off cycle) in order to calibrate the BOLD responses in SE acquisitions; 3) as in 2), but with a different stimulation design: 1 on/ 2off scans in order to saturate slow (e.g of hemodynamic origin) signals and to detect primary neuronal current magnetic effects (orthogonality of the neuronal and the hemodynamic responses is provided). Synchronisation of SE acquisition with the measured ERP components was performed in order to avoid signal refocusing. Each subject was positioned to maximize the orthogonality between the dipole orientation and the static magnetic field; slice positioning was chosen according to the location of the estimated dipole while slice orientation was selected perpendicular to the dipole orientation. Activation maps were obtained by SPM2, through correlation analysis with modelled neuronal and hemodynamic responses and statistical thresholding ($p<0.05$ corrected for family-wise-errors in 1); $p<0.001$ uncorrected for 2) and3)).

Results and Discussion

In Table 1, onset, peak and offset latencies for the first component (C1) are reported; orientation (in cartesian coordinates), location (with respect to a Tailarach standard space) and dipole intensities are also shown. For each subject, both primary and associative visual cortices were significantly activated in BOLD GE images (see 1) in Methods) , with maximum t-values ranging from 7 to 14 between different subjects. Only few activated voxels were found for SE images relative to the block design (see 2) in Methods), with maximum t-values around 3.5-4. Only in one subject (a, in Table 1), a stimulus correlated and neuronal current related decrease in MR phase was found in the primary visual area (t=3.3). This was confirmed by a second acquisition on the same subject, in an adjacent voxel (t=3.6). However expected corresponding positive phase changes were not detected, while in other brain regions (not detected in the BOLD activation maps) negatively correlated phase changes were found. In amplitude images no consistent neuronal current related signal changes were found.

The estimated dipole intensities are higher than the minimum dipoles detected by MRI [5]. However othogonalisation with respect to the main magnetic field was not perfect with the presence of non-negligible z-components. The possible unwanted contributions from BOLD signal components to the primary effects of neuronal currents were reduced by the use of a SE acquisition (a block design, dominated by hemodynamic effects yielded t-values around 3-4), as well as by experimental design that saturated slow responses (expected t-values around 1.5-2). We conclude that more experimental evidences are needed in order to establish the feasibility of detecting magnetic effects induced by neuronal currents.

References

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Table 1

	Latency (ms)			Orientation (Cartesian)			Location (Talairach, mm)			(nAm)
Subject	onset	peak	offset	X-orie	Y-orie	Z-orie	X-pos	Y-pos	Z-pos	D. Int.
a	50	76	115	-0.11	-0.54	0,83	9	-87	-4	-50
b	55	80	115	-0.17	-0.56	0,81	8.05	-80	3	-40
c	50	75	100	-0.67	-0.77	0,64	10	-84	-2	-27