Visual Motion Processing: Simultaneous Recording of Visual Evoked Potentials and BOLD MRI Activations

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Introduction

The technical feasibility of combined EEG and blood oxygenation dependent (BOLD) MRI recordings of human brain activation has been demonstrated in a number of reports. The combination of these methods offers the opportunity to explore brain function at both high temporal and spatial resolution. However, to fully understand the physiologic correlates underlying either method and their relationship to neural processes, identical stimuli and basic paradigms commonly used with either technique need to be studied. Here, we focused on human visual area V5 and specific aspects of visual motion processing. We investigated the electrophysiologic and BOLD MRI responses to low- and high contrast pattern-reversal (flicker) visual stimuli and low-contrast random dot motion stimuli emphasizing either onset of motion or continuous motion with frequent reversal of direction.

Methods

Visual stimulation: 5 healthy subjects were studied (25±4 years). MR-compatible liquid crystal display goggles (Resonance Technology Inc. USA) were used to show a starfield simulation consisting of 700 randomly positioned dots (size approx. 0.1°, speed 6-24°/s, dot luminance either 20 % or 100% of goggles' maximum, dot-free aperture of approx. 6°, red fixation cross provided). Three different stimulus conditions (each lasting 12s) were arranged in separate block designs (Fig. 1): flicker at 500ms intervals, motion onset with 200ms motion followed by 1000ms stationary starfield and motion reversal with alternating starfield direction every 1000ms. Each stimulus was contrasted with stationary random dot starfield patterns of equal overall luminance and contrast (lasting for 18s).

EEG: EEG was recorded continuously using 32 electrodes (10/20-standard, BrainAmpMR by Brainproducts, Germany). Gradient and cardioballistic artefact removal was done offline. Data was segmented at each timepoint of motion-onset, motion-reversal and flicker-alternation and a per-channel average was calculated. Individual channels were pooled for further analysis.

fMRI: Imaging was done at 2.9T (Siemens Trio, Erlangen, Germany) using an 8-channel phased-array Siemens headcoil. A gradient-echo echo-planar-imaging (EPI) sequence was used for BOLD MRI at 2mm isotropic resolution (TR 2000ms, TE 36ms, flip angle 70°, 128x128 matrix, frequency-selective fat suppression, 20 slices per volume, orientation transverse-to-coronar along the calcarine fissure). BOLD MRI data was analyzed using a boxcar reference function shifted by 2 volumes (4s) to model the hemodynamic response lag. Correlation coefficient analysis was done using in-house software and BrainvoyagerQX software (BrainInnovation, Netherlands) [3]. Event-related averaging of % BOLD MRI signal changes and voxel count were constrained to activated clusters in individually located bilateral V5.

Results

The N2 component of motion-related visual evoked potentials (VEP) is highly sensitive to luminance contrast and responds most prominently to motion stimuli [1]. Here, N2 component of VEPs was most pronounced over left temporal electrodes (LT, 300ms) during 'onset' stimulation. During 'reversal' stimulation no particular VEP component could be distinguished [Fig. 2]. P1 component could be seen during 'flicker' stimulation predominantly over occipital electrodes (Oz, 150ms/182ms).

Event-related averaging revealed a significant difference in BOLD MRI response strength of 0.35% during 'onset' stimulation and 0.7% during 'reversal' stimulation (paired Student's t-tests: left p=0.002; right p=0.012) [Fig. 3]. Activated voxel count in V5 was consistently lower during 'onset' stimulation (left 1160±432; right 1619±731) than during 'reversal' stimulation (left 4640±3118; right 5176±4259) [Fig. 4]. 'Flicker' stimulation showed an activated voxel count of 1714±939 (left) and 4570±3526 (right).

Discussion

Whereas motion-evoked VEPs were most prominent during stimulation with discontinuous motion ('onset'), BOLD MRI showed strongest signal changes during continuous motion ('reversal'). Part of these findings may be attributed to adaptational processes [4,5]. Involvement of inhibitory neuronal networks is expected to attenuate VEPs while still requiring metabolic demands that lead to sustained BOLD responses. The understanding of these physiologic correlates underlying both BOLD MRI and electrophysiologic recordings is essential to exploit the potential of combined EEG/MRI studies of human brain function.

References

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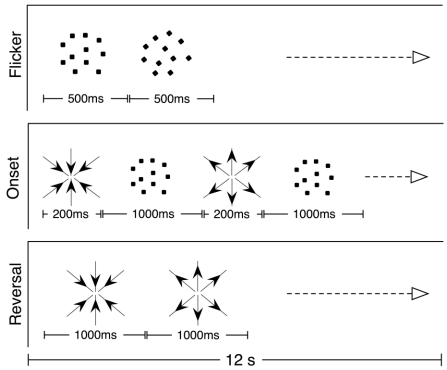

Fig. 1 Visual stimuli.

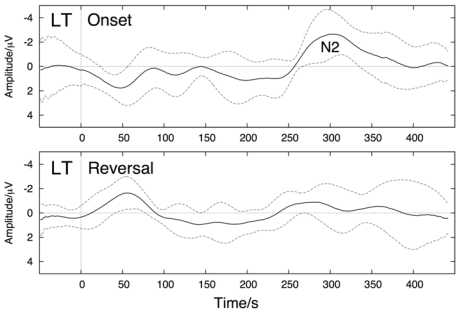

Fig. 2 Grand average of VEPs.

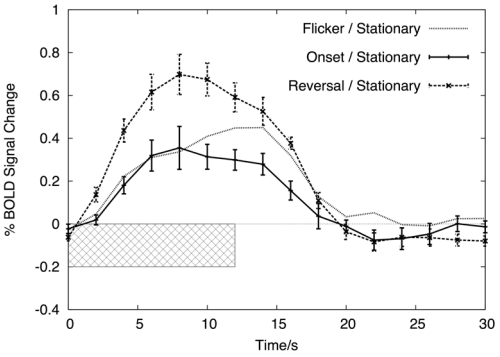

Fig. 3 BOLD MRI signal changes.

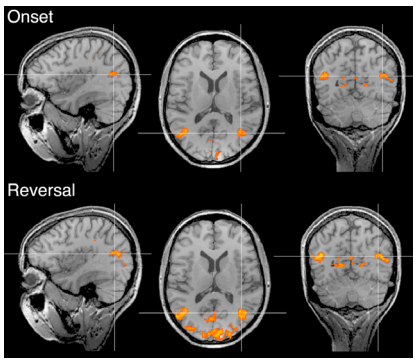

Fig. 4 Representative activation maps.