Spontaneous activity in the visual cortex persists during visual stimulation: a 7T study

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Purpose:
The aim of the present study is to investigate whether spontaneous activity in the visual cortex is modulated by visual stimulation. With regard to spontaneous activity in other cerebral regions, previous works showed that both the default mode [1] and the sensory-motor network [2] activities continue during a wide range of tasks, being respectively modulated/unperturbed by stimulation.

Methods:
Seven subjects (4m/3f, age 32±4) participated in the study (IRB approved protocol). GE-EPI BOLD fMRI was performed at 7T (GE Medical Systems) using 16-elements of a NOVA 32-channel receive-only detector array and the following parameters: TE = 32ms; TR = 3s; F.A. = 75deg; N. slices = 36; voxel dim: 1.25x1.25x2mm^3; slice spacing: 0.2mm; SENSE rate = 3. First, a 360deg rotating wedge (Fig.1) stimulation (retinotopy, N. scans = 172) was employed as functional localizer for three regions of interest (Fig. 2, $p < 10^{-5}$, uncorrected for multiple comparisons). Next, three conditions were investigated (N. scans = 115): 1) "F+S" = fixation to a central dot during the presentation of a visual stimulus (Fig. 1, 8Hz flickering B/W wedge displayed with a 6s ON/OFF cycle in the lower left quadrant, position LL); 2) "F" = fixation without stimulation; 3) "EC" = resting with eyes closed. Pre-processing (FSL4.0) included slice-timing, motion correction, co-registration between different 4D-volumes, and removal of physiological noise related to the respiration volume per unit time [3]. We identified the stimulus *evoked response* via GLM analysis (AFNI) after high-pass filtering the data at f_C = 0.073Hz. The background *spontaneous network* was obtained by correlating each voxel signal with the average time-series in ROI3, after low-pass filtering at f_C.

Results:
We show the evoked (green) activity, the spontaneous fluctuations (red) and their overlap (yellow) for one subject ($p < 10^{-8}$, uncorrected) during condition F+S in Fig. 3A. Spontaneous activity during conditions F and EC is also displayed in Fig. 3A. For low-pass filtered data-sets and all the three conditions, we computed Pearson correlation coefficients (r) of the average time-serie in ROI3 with the signals of all other voxels: the mean ± s.e. across voxels pertaining to ROI1 (green) and ROI2 (blue) is displayed for all the investigated subjects in Fig. 3B, and the group average ± s.e. in Fig. 4. As a measure of spontaneous fluctuations amplitude, we show the standard deviation of the average low-pass filtered signal in ROI1,2,3 in the three conditions (mean± s.e. over subjects) in Fig. 5.

Conclusions:
During stimulation, spontaneous and evoked activity overlap in the visual cortex at a 1.25mm in plane resolution: our findings (Fig. 4, F+S) show that the *correlation strength* of spontaneous activity in the stimulated area (ROI1) with neighboring visual areas (ROI3) is not significantly different at p = 0.05 from that in the ipsi-lateral non-stimulated visual cortex (ROI2). Nevertheless, spontaneous activity during fixation with and without stimulation is reduced ($p<0.05$) with respect to the eyes closed condition (Fig. 4, F+S/F versus EC). A similar finding is encountered for the *signal amplitude* of the spontaneous network (Fig. 5, F+S/F versus EC). We conclude that spontaneous activity in the visual cortex is not significantly perturbed by stimulation but it is modulated by eye fixation/closure.

References: [1] Raichle ME et al., *PNAS*, **98**: 676-682, 2001. [2] Fox MD et al., *Nat Neurosci*, **9**: 23-25, 2006. [3] Birn RM et al., *Neuroimage*, **31**: 1536-1548, 2006.

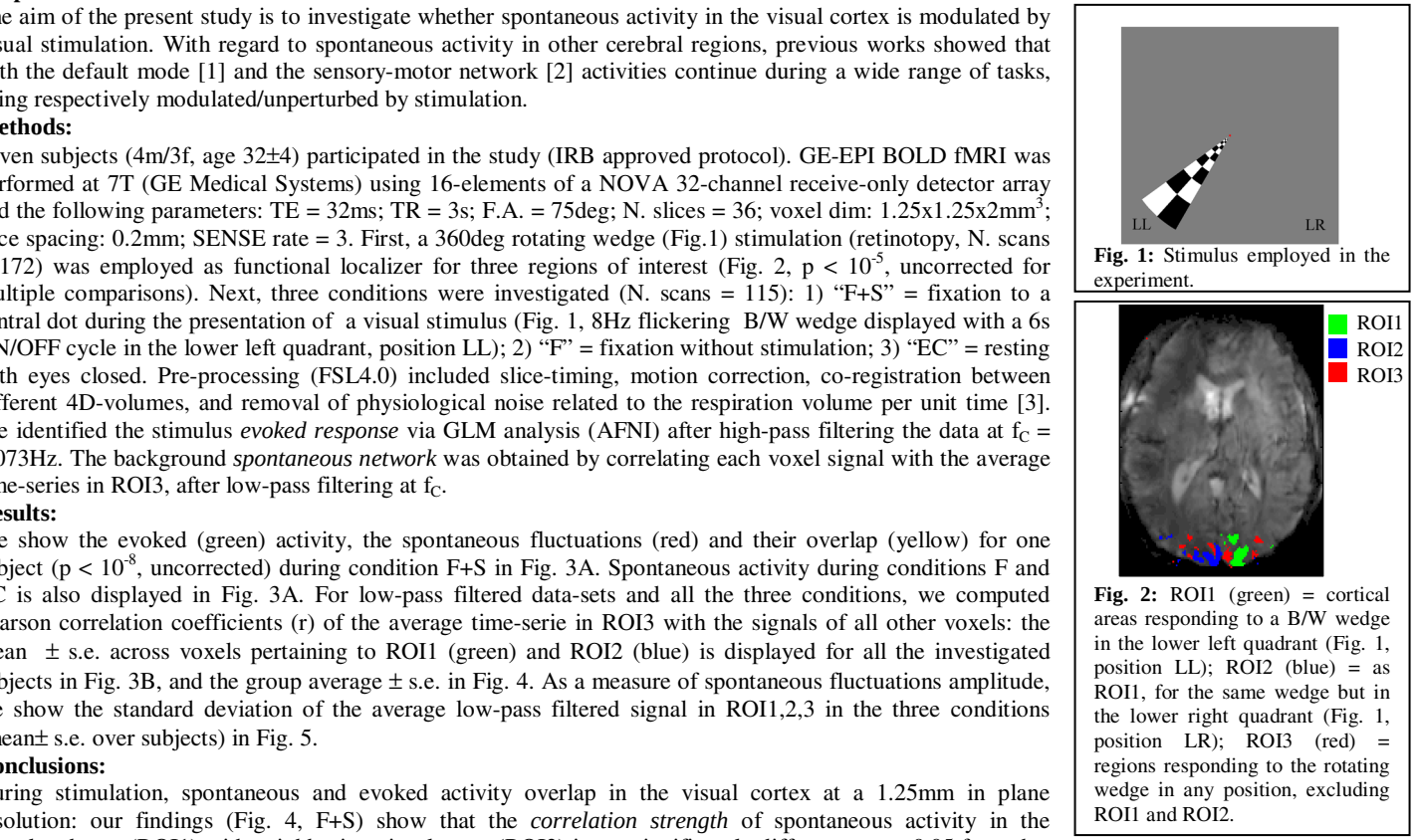

Fig. 1: Stimulus employed in the experiment.

Fig. 2: ROI1 (green) = cortical areas responding to a B/W wedge in the lower left quadrant (Fig. 1, position LL); ROI2 (blue) = as ROI1, for the same wedge but in the lower right quadrant (Fig. 1, position LR); ROI3 (red) = regions responding to the rotating wedge in any position, excluding ROI1 and ROI2.

Fig. 3: A) Maps of spontaneous (condition F+S, F, EC) and evoked (condition F+S) activity for one subject. B) Quantification of the correlation strength (r = Pearson correlation coefficient) of spontaneous fluctuations.

Fig. 4: Group analysis of the correlation strength of spontaneous fluctuations.

Fig. 5: Group analysis of the amplitude of spontaneous fluctuations.