An EEG homologue of the negative BOLD response as measured at 7 Tesla

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Introduction The basis of fMRI experiments is a tight coupling of neural activity with the BOLD response in both space and time. However, the negative BOLD signal, though often reported as 'deactivation', may also be caused by so-called blood-steal effects[1]. Here, we studied the negative BOLD signal using fMRI data acquired at 7T and separately acquired EEG data from the same individuals, using the latter as a direct measure for neural activity. A cross-modal protocol[2] in which negative BOLD signal is found at some spatial distance from the positive BOLD signal was used to accommodate the limited spatial resolution of EEG.

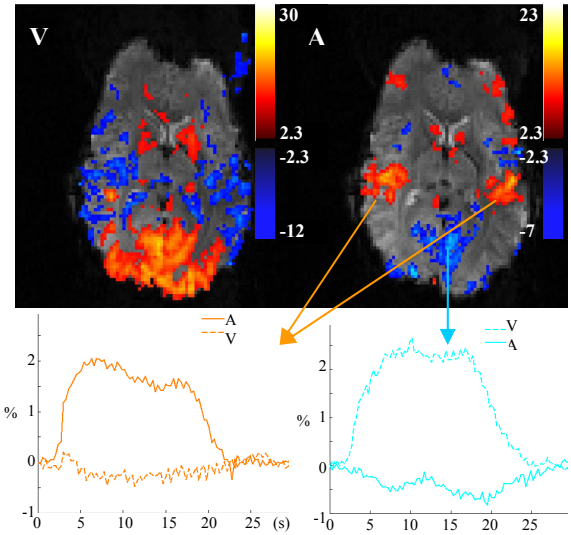

Figure 1. fMRI results. Activation maps from a representative subject of visual (V) and auditory (A) tasks shown overlaid on a volume of the fMRI data train. Positive BOLD signal is shown red-yellow, negative BOLD signal blue. Lower panels: timecourses during V and A stimuli from ROIs in auditory (orange) and visual (blue) cortex.

Methods Three subjects were scanned on a 7T MRI system (Siemens Medical solutions, Erlangen, Germany) using an 8 channel rf-coil (RAPID Biomedical GmbH, Germany) for rf-transmit and receive. Acquisition parameters were: resolution 2.3 * 2.3 * 3 mm^3, field of view 220 * 220 mm^2, TE 28 ms. One volume, consisting of 5 slices aligned so as to cross both the occipital and temporal lobes was acquired every 300 ms. fMRI data were processed with FEAT from FSL, FMRIBs software library.

In a separate session for the same subjects, EEG data was acquired at 1024Hz through a 160-channel Biosemi ActiveTwo system (Biosemi, Amsterdam, Netherlands) referenced to the CMS-DRL ground. Trials were visually inspected and rejected when including artefacts. A rejection criterion of ± 80µV was applied at all electrodes. Data from artefact electrodes were interpolated using 3-D splines and band-pass filtered between 0.05 and 40Hz. No baseline correction was applied. Voltage measurements for each time-frame within the range 79-130ms post-stimulus onset (i.e. to include the first global field power peak in the evoked responses) were extracted and the activation during those periods compared to activity during 100ms of baseline. For each time frame the intracranial sources distribution was obtained[3]. A quantitative comparison was obtained by an unpaired T-test analysis ($\alpha<0.001$) considering each inverse solution a sample representative of the activity during the post-stimulus or baseline period.

Identical stimulation paradigms were used for fMRI and EEG experiments: Visual stimulation (V): 15s ON – 15s OFF 8Hz flashing checkerboard, repeated 6 times. Auditory stimulation (A) 15s ON - 15s OFF pulsed white noise presentation, repeated 6 times. Audio-visual stimulation (AV): semi-randomised blocks of flashing checkerboards (v'): 6 x 15s, pulsed white noise (a'): 6 x 15s and a simultaneous combination thereof (av'): 6 x 15s, all interspersed with 15s OFF.

Results and Discussion In all A and V experiments, negative BOLD signal was found in the non-stimulated cortical lobe. Example SPMs and timecourses are shown in Figure 1. AV experiments yielded negative BOLD signal in the auditory cortex during v' blocks, but not, unexpectedly, in the visual cortex during a' blocks. The av' blocks yielded only positive BOLD signal in visual and auditory cortex, as expected.

The average amplitude of the negative BOLD was smaller than that of the concomitant positive BOLD responses (+1.3% ± 0.1 and -0.9% ± 0.1 in A and a' blocks, +1.9% ± 0.1 and -0.7% ± 0.03 in V and v' blocks), while the area was larger (16 ± 3 cm^3 (p) and 41 ± 13 cm^3 (n) in A and a' blocks, 47 ± 8 cm^3 (p) and 54 ± 6 cm^3 (n) in V and v' blocks).

EEG results showed increased activation vs. baseline for all three tasks in the appropriate cortices (Figure 2, red-yellow, top panels) and a decrease in the non-stimulated cortex (blue regions) in the A/a' and V/v' conditions, but not in the av' condition, demonstrating a qualitative correspondence with the obtained fMRI responses.

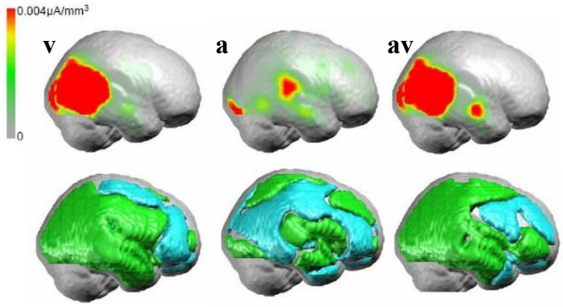

Figure 2. EEG results. Top panels show the mean of the linear source estimations (red-yellow) calculated over the 74-124 ms post stimulus period within the AV experiment rendered on the averaged MNI brain. Bottom panels show results of the statistical contrasts of the source estimations between ERPs during 79-130 ms post-stimulus and baseline. Colours indicate regions where activity was significantly higher (green) or significantly lower (blue) than baseline.

Conclusion The combination of high-field fMRI data with EEG measurements allows the investigation of the neural signal underlying the BOLD responses. Preliminary data analysis shows an EEG homologue of the negative BOLD signal; to what extent this EEG component predicts all negative BOLD signal remains to be determined.

References [1]Shmuel, A., et al 2002. Neuron 36, 1195-1210. [2]Laurienti, et al 2002. J Cogn Neurosci 14, 420-429. [3]Grave de Peralta Menendez, R., et al. Brain Topogr 14, 131-137. Supported by the Centre d'Imagerie BioMédicale of the UNIL, UNIGE, HUG, CHUV, EPFL and the Leenaards and Jeantet Foundations and the SNF grant K-33K1_122518/1.