Transient and Steady-State Components of the fMRI BOLD Signal in Somatosensory Cortex

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Motivation and Hypothesis: Electro- and magnetoencephalography (EEG and MEG) recordings indicate that a sustained vibrational touch stimulus evokes two different types of responses: a transient (T) component shortly after stimulus onset and a steady-state (SS) component at the frequency of the stimulus, that continues throughout the stimulus duration. A recent MEG study showed that the associated dipoles in the primary somatosensory cortex (S1) are spatially separated by approximately 3-5mm [1]. The goal of this study is to integrate similar components into the model of neuronal activity for fMRI analysis and to develop an experiment to determine whether both components can be distinguished using high resolution fMRI. Previous data suggests that this might be possible[2]. Our hypothesis is that T and SS components of the BOLD signal will reveal physiologically relevant differences in the activation pattern in S1.

Methods: Subjects received randomized 1, 4, or 7 s vibrational stimuli (see Fig. 1) at 23 Hz using an inflatable air bladder on their left middle finger. To increase attention, subjects were ask to respond to the offset of each stimulus by pressing a button with their right index finger. Three or four runs of 45 stimuli each were recorded. Neutral pictures were shown during each run to avoid closing of the eyes and drowsiness. A short inter-stimulus interval of 10s was chosen to allow for enough trials for subsequent MEG experiments at a reasonable run time of 10:40min. EPI BOLD images were acquired on a Siemens 3T Trio (Erlangen, Germany) with TR/TE/Flip of 1s/30ms/50°. Twelve oblique coronal 3mm thick slices were positioned contiguously to include S1 and S2 (secondary somatosensory cortex) areas. The field-of-view was 20cm with 96x96 matrix size resulting in 2.1x2.1x3.0 mm voxels. Three healthy adults (26-29 years) were scanned. The data were corrected for heart beat and respiration, slice timing, and motion. No smoothing was done for the presented data. The AFNI[3] general linear model (GLM) was used to fit the data with two hemodynamic responses components (T and SS, see Fig. 1). The components were generated by convolving a transient (1s) pulse of neural activity at stimulus onset and a conventional boxcar functions of the same length as the stimulus with a canonical hemodynamic impulse response function (IRF) with 1.5s delay time, 4.5s rise time, 3.5s fall time and no undershoot. A conventional fit with only the boxcar component was also performed for comparison.

Fig. 1:

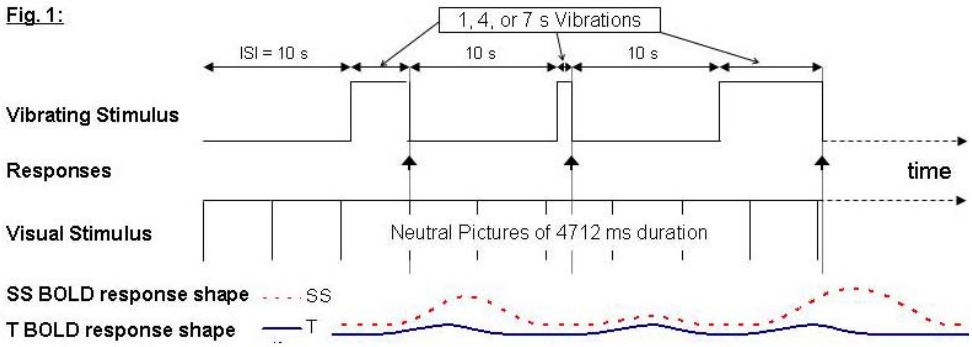
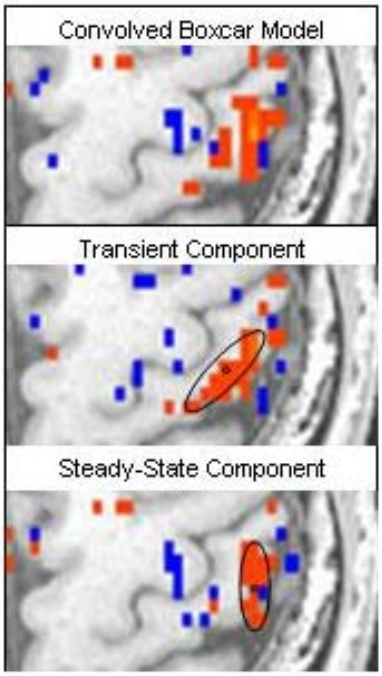


Fig. 2:



Results: All subjects showed a number of voxels in S1 in which the transient component improved the data fit with $p < 0.005$. Fig. 2 is an example from subject one showing that the activation maps of the transient and steady-state components differ from each other as well as from the standard IRF-convolved boxcar model. The centroids of the activated T and SS areas, indicated schematically in the figure, differ obviously and may be related to the corresponding source locations in an MEG experiment.

Conclusion: Transient and steady-state components of the BOLD signal can be extracted and yield a more refined picture of brain activation in S1. The differences in the activation maps may be related to transiently and continuously activated neuronal populations.

Future Direction: This is a preliminary report on the initial findings of a larger ongoing study in 15 subjects. Subjects are being scanned with both fMRI and MEG with identical paradigms. We will examine whether transient and steady-state activation centres in fMRI correspond with MEG transient and steady-state dipole source locations. We will also consider more sophisticated data processing to allow for locally variable hemodynamic IRFs.

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2. Nangini, C., et al., Magnetic Resonance in Medicine, 2005. **53**(2): p. 304-11.
3. Cox, R.W., Computers & Biomedical Research, 1996. **29**(3): p. 162-73.