# Temporal and Spatial Characteristics of BOLD fMRI Responses to Prolonged Tactile Stimuli in Somatosensory Cortex

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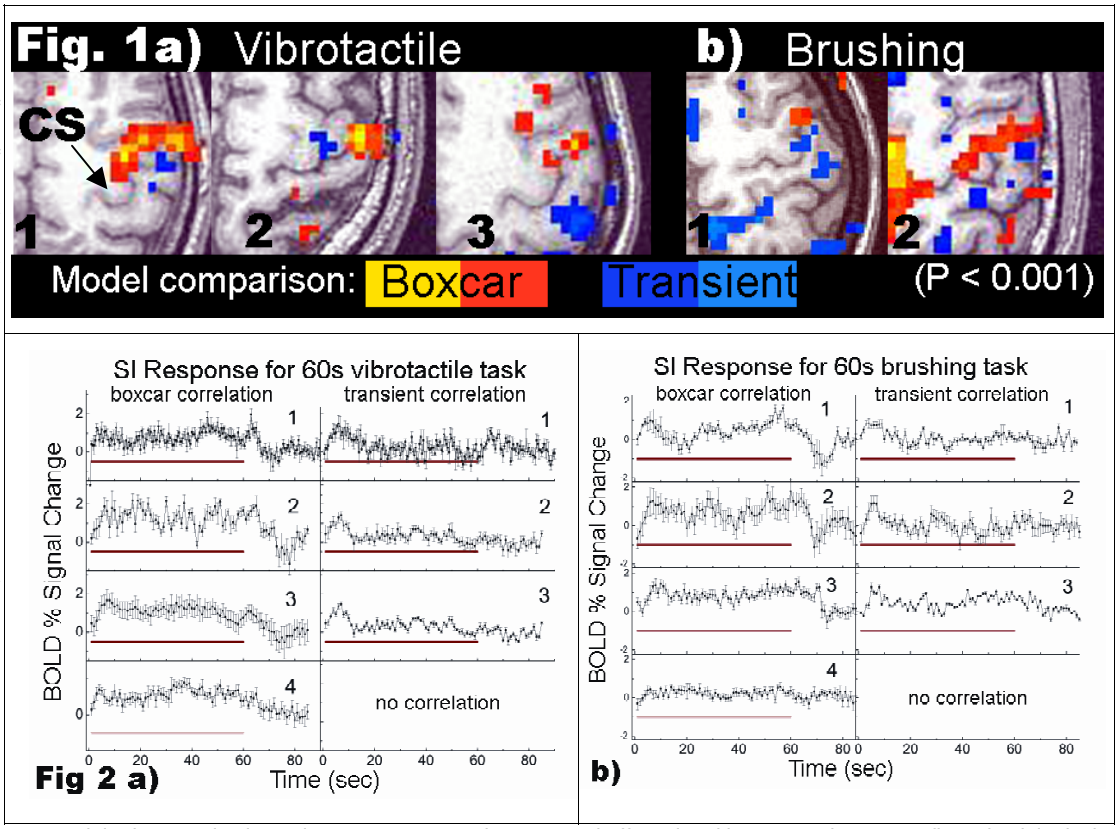
**Introduction:** The utility of fMRI hinges on the degree to which hemodynamic changes correlate with neural activity. Despite the complex interactions between neurons and their vasculature, it is commonly assumed that the fMRI signal is a linear transform of the stimulus input. Several functional imaging studies have shown a departure from linearity as evidenced by decreasing signal amplitude with increasing stimulus duration, postulated by some to arise as a consequence of decreases in neural activity[1]. It has also been suggested that such signal modulations are dependent on the specific stimulus applied[2,3]. This issue is still under debate, and has not been explored in the somatosensory system. Consequently we investigate whether modulations in fMRI responses on short and long time scales are present in the primary somatosensory cortex (SI) using different stimulus parameters.

**Methods:** FMRI was performed on healthy right-handed adults at 3 T (Signa Eclipse, GE Medical Systems, WI) using single-shot spiral k-space acquisitions (FOV = 20 cm, TE/TR/θ = 30/1000/50°, 15 axial slices 5 mm thick). Passive vibrotactile stimuli were delivered[4] with 20 Hz square waves to the volar surface of the right index and middle fingers in four subjects for 60 s followed by 25 – 30 s of rest, repeated 5 – 7 times. Automated, 60 s brushing stimuli were delivered using a swinging bar with a sandpaper surface to the same fingers in four subjects at 5 Hz for 7 blocks separated by 25 s of rest. Six subjects performed finger tapping, visually cued at a rate of 1 Hz, as a control task. Anatomical axial images with high spatial resolution were acquired using conventional spoiled gradient echo imaging. Activation maps were created using AFNI[5]. A boxcar, convolved with a hemodynamic response function (HRF) (peak 6 s) and a transient consisting of the HRF itself were used to isolate sustained and transient BOLD signal characteristics, respectively.

**Results:** As shown in Figs. 1a) and b), difference activation maps ($p<0.001$) associated with boxcar (red) and transient (blue) models of the SI BOLD signal show spatial segregation for a number of subjects across both stimulus types. Sustained vs. transient features could not be segregated for subject 3 in the brushing task (data not shown). Transients were not found in subjects 4 (both tasks). Maps show heterogeneous distribution of these signal characteristics in pre-central gyrus (PreCG), central sulcus (CS) and post-central gyrus (PoCG) for both tasks. Average SI time series for each BOLD signal correlation are shown in Figs. 2a) and b). Sustained responses (left columns) showed suggestions of onset and offset transients. Transient responses (right columns) peaked ~6 s after stimulus onset and returned to baseline ~9 s later. Motor task responses (not shown) were highly correlated to the boxcar, and showed no transients.




**Discussion:** In all subjects we observed sustained activation in the PreCG and PoCG areas, as expected, using the conventional boxcar model. These activations also appear to contain onset and offset signal increases that may reflect physiological properties of stimulus-specific neurons. Our additional correlation analysis shows the presence of transient BOLD signals that, although heterogeneous across subjects, are spatially distinct from areas with sustained responses. These signals were observed robustly in 3 of 4 subjects given vibrotactile stimuli, and 2 of 4 subjects given brushing stimuli. It is evident that these signals can be missed on the basis of conventional, linear boxcar correlation for prolonged stimulus durations, and that they are important in assessing the stimulus-BOLD signal relationship. Similar results have been reported for brain regions in the olfactory system[7]. We will further investigate and interpret these findings by optimizing our methodology (i.e. increasing fMRI spatial resolution and SNR with surface coils), investigating other stimulus types, and by exploring several factors such as attention and specific physiological properties of neurons that play a role in fMRI signal modulation. We also plan to obtain neural correlates to these fMRI signals using EEG, following previous work in the visual system[8].

**References:** 1. GM Boynton et al, J Neurosci 16:4207:4221 (1996) 2. PA Bandettini et al, HBM 5:93-109 (1997) 3. AM Howesman et al, MRM 16(1):1-11 (1998) 4. SJ Graham et al, MRM 46:436-442 (2001) 5. RW Cox, Comput Biomed Res 29:162-173 (1996) 6. HR Heekeren et al, Phil Trans R Soc Lond B, 352:743-750 (1997) 7. Poellinger et al, NeuroImage 13, 547-560 (2001) 8. H Obrig et al, NeuroImage 17, 1-18 (2002)