

# High Resolution fMRI for Finger Somatotopic Mapping at 3T using a Novel Vibrotactile Stimulator

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**Introduction** Mapping the somatosensory cortex using fMRI is useful for characterizing the somatosensory system and understanding the neuronal organization. Vibrotactile stimulation is one of the most widely used stimuli for somatotopy. Although various stimulators have been developed, design and construct a MRI-compatible stimulator that is applicable for a wide-range of stimulation frequencies is of great challenge. This study described the development of a novel magneto-driven, MRI-compatible, vibrotactile stimulator. We implemented high-resolution fMRI studies with 1 mm isotropic resolution to map finger somatotopy. In addition, a frequency-response curve for the flatter tactile sensation (5-50 Hz) was explored while investigating vibration sensation at higher frequency is also possible.

**Methods** The entire stimulator is housed inside a 10x2.5 cm rectangular casing and a hole of 1.5cm diameter was made on the top end of the casing which functions as the sole region of contact with the subject's fingers. The vibration device consists of a flexible mechanical shaft driven by an adjustable microprocessor control box. The use of a shaft for the transmission of the mechanical energy enables exact definition of the vibration frequency and the vibration amplitude. The electrical input to the vibrotactile device is regulated using a control box made in house. Regulation of the control box occurs via a desktop computer and the control is initiated from the software program.

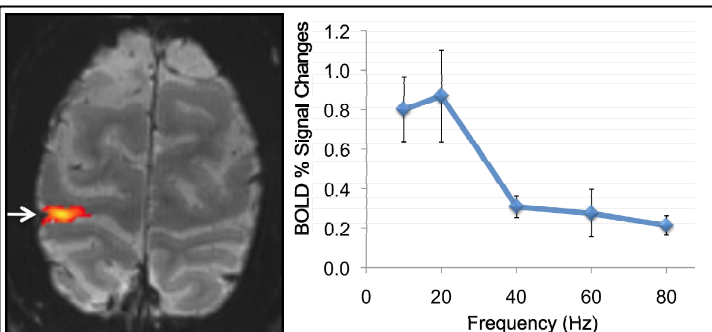
Four BOLD fMRI sessions were performed on three normal subjects (25-30 yr). MRI studies were performed on 3T Siemens TIM TRIO with a standard 12-channel head coil. BOLD fMRI was acquired using gradient echo-planar imaging with TR = 2000, TE = 30 ms, matrix = 128x128, field of view (FOV) = 12.8x12.8, resulted in 1 mm isotropic resolution, and 25 slices. Five repeated fMRI stimulation trials were measured in each session with different vibrotactile stimulation frequency (10, 20, 40, 60, 80 Hz at 0.6A) in a randomized order. Subject was scanned with their right index finger placed on the simulator and was instructed to keep their eyes opened during the experiment. Stimulation paradigm used a block design of eight 20s-on/off epochs and end with a rest period. In one subject, a 0.3A, 40 Hz stimulations were applied on the ring finger and the little finger with the same experimental paradigm. Data were processed using FMRIB Software Library (FSL). Activation maps were threshold to  $Z > 2.3$  ( $p < 0.01$ ). BOLD percent changes were tabulated for region-of-interests of the primary (S1) somatosensory cortex at different frequencies.

**Results and Discussions** The proposed stimulator was constructed entirely from non-ferromagnetic parts, uses magneto-mechanical principles which rely on the Lorentz forces generated from small oscillatory currents through coils in the device to deliver stimulation using computer control, and stimulates the fingers to ensure robust somatosensory activations.

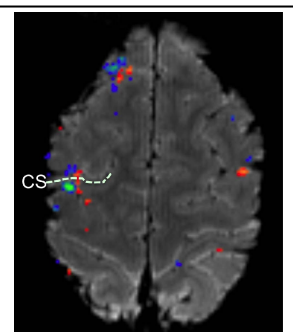
**Figure 1** shows the fMRI activation map from a representative subject at 20Hz. The activation was localized within the central sulcus and the post-central gyrus encompassed S1. The group-averaged frequency-response curve showed that the optimal stimulation frequency for our device was at 20 Hz. At this particular frequency, the Meissner corpuscle responsible for the tap, flutter sensation is activated (5-40 Hz). We did not explore higher frequencies ( $> 100$ Hz) in this study. However, we suspected another peak response might occur at 200 Hz, which is suggested to be the optimal frequency for vibration sensation (the Pacinian corpuscles). **Figure 2** shows the BOLD activation map with two-finger discrimination (the ring finger and the little finger). The locations of the activations were consistent with known finger somatotopic mapping, i.e. little finger is mapped at more medial-superior directions compared to other fingers. Studies are on going to provide the full finger somatotopic mapping using high-resolution fMRI.

**Conclusions** This study described the development of a novel magneto-driven, MRI-compatible, vibrotactile stimulator. We implemented high-resolution fMRI studies with 1 mm isotropic resolution to map finger somatotopy to test the feasibility. In addition, a frequency-response curve for the flatter tactile sensation (5-50 Hz) was explored while investigating vibration ( $> 100$  Hz) sensation is also possible. This study established a simple device and high-resolution protocol for future neuroscience applications exploring the somatosensory system with sophisticated experimental design.

**References:** 1. Stefan M. Golaszewski, *NeuroImage* 17, 421(2002). 2. M. Mallar Chakravarty, *J Neurosci Methods* 184 (2009). 3. Richard W. Briggs, *Magnetic Resonance in Medicine* 51(2004). 4. Andreas Weibull, *Magnetic Resonance Imaging* 26 (2008). 5. Renate Schweize, *NeuroImage* 42 (2008) 28–35



**Fig 1.** (Left) BOLD fMRI activation map of 20 Hz vibrotactile stimulations from a single subject (arrow: central sulcus). (Right) Group-averaged BOLD % signal changes at different vibratactile frequency (mean  $\pm$  s.d.).



**Fig 2.** BOLD activation map with stimulation at the ring finger (blue-green) and the little finger (red-yellow). (Z: 2.3-5)