Rapid digit mapping in the human brain at 3T

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Introduction

Somatosensory mapping in the human brain by functional MRI is of great interest for addressing a wide variety of issues ranging from understanding basic mechanisms to improving presurgical mapping. However, such studies are difficult due to both the limitations imposed on stimulus delivery hardware by the MR environment and the high resolution necessary to reliably and rapidly distinguish between adjacent cortical representations[1] within individual participants. We have developed an MRI compatible pneumatic stimulation system and combined it with high-resolution, rapid event-related scanning protocols at 3T in order to map individual digit and face representations in the human brain. The system is modeled after the pneumatic stimulator described by Huang and Sereno[2]. As there are no moving parts, the system generates no RF or susceptibility-related artifacts and may be placed anywhere on the body, including inside the RF head coil in order to stimulate areas of the face. By using this device together with high-resolution BOLD EPI imaging sequences, we have been able to produce detailed maps of the somatosensory representations of the digits in individual human subjects with an acquisition time totaling approximately 14 minutes.

Methods

The system consists of 16 lengths of flexible tubing, each connected to a length of ¼ inch Loc-Line™ modular adjustable hose and terminated with a 1/16 inch diameter nozzle. The tubing is connected to a bank of high-speed solenoids (NVKF334, SMC Pneumatics, Indianapolis, IN) and enters the magnet room through a waveguide. A compressor provides pressurized air to the solenoids, which are computer controlled by a multifunction DAQ with clocked IO (PCI-6229, National Instruments, Austin, TX) and LabView™ software. The solenoids can be operated at frequencies of up to 10 Hz. Each of the 6 lines is connected to an adjustable-flow valve in order to regulate the air flow at each nozzle.

Figure 1 *Pneumatic stimulators attached to subject's hands.*

For digit mapping, the flexible tubing is connected to the Loc-Line™ hose via a custom-built manifold. The manifold is attached to a ¼" sheet of plastic to which the subject's hand is secured with Velcro straps (figure 1). The Loc-Line™ hose is adjusted for each subject so that the nozzles are directed at the pads of the thumb and fingertips.

In this study, stimuli consisted of pulsed air puffs delivered during a single run to four targets, alternating with rest. The air puffs are pulsed at 8 Hz with a 50% duty cycle. To insure attention, subjects were asked to count the number of oddball (4Hz) stimuli delivered throughout the run. The rest periods varied between 3 and 6 seconds in duration. Each target was stimulated in pseudo-random order a total of 32 times, for a total duration of approximately 14 minutes. An additional two minutes of rest was included at the beginning of the trial in order to establish a quiet baseline.

All scanning was performed in a Siemen's Allegra 3T scanner, using a four-channel phased-array head coil. An EPI-BOLD sequence was used with a 144 × 216 mm field of view and a 96 × 144 matrix size for an in-plane resolution of 1.5 × 1.5 mm. Fifteen 2.5 mm thick coronal slices were obtained with a TR of 1030 ms and a TE of 30 ms. The position of the rostralmost slice was determined on the basis of a functional localizer scan during which individual participants made movements of the hands or lips. This enabled full bilateral coverage of primary (S1) and secondary (S2) somatosensory cortices.

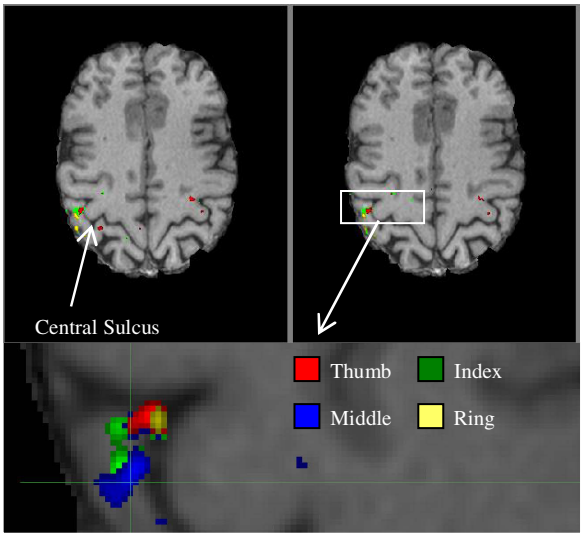

Figure 2 *Digit maps of the left hand for a single subject.*

Results and Discussion

Figure 2 shows significant activations (relative to resting baseline) associated with stimulation of the left thumb, index, middle, or ring fingers of a single subject. At this resolution, we find voxels that respond selectively to stimulation of individual digits in both the contra- and ipsilateral S1. As expected, responses are more pronounced in the contralateral hemisphere.

Conclusions

We have demonstrated that it is possible to obtain high-resolution somatosensory maps of separate digits for individual participants reliably and rapidly in a 3T MRI scanner. The pneumatic stimulus delivery system is highly adaptable to a wide variety of experimental protocols and subject populations. When used in combination with high resolution fMRI and a rapid event-related protocol, it provides an efficient tool for investigating cortical somatosensory representations non-invasively.

[1] Sanchez Panchuelo R, Schluppeck D, Francis S, Bowtell R. Mapping human somatosensory cortex with fMRI at 1 mm isotropic resolution. Proceedings 16th Scientific Meeting, International Society for Magnetic Resonance in Medicine. Toronto; 2008. p 2522.
[2] Huang RS, Sereno MI. Dodecapus: An MR-compatible system for somatosensory stimulation. Neuroimage 2007;34(3):1060-1073.