Development of a new fMRI compatible pneumatic vibrotactile stimulator

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1. Introduction

Vibrotactile devices have gained popularity in functional magnetic resonance imaging (fMRI) as an effective technique that can be used to evoke somatosensory responses. Several techniques have been recently proposed to deliver vibrotactile stimulation [1,2,3,4], however these techniques are often limited in one or more of the following areas: 1) They are often unable to deliver stimulation without the use of ferromagnetic parts, 2) They are unable to produce reproducible stimulations or 3) They are limited in size and thus are incapable of stimulating large areas. In this abstract we propose the design and construction of a novel computer controlled vibrotactile stimulator which addresses these limitations. Here we outline the design and construction of this device and the control system for the device. The results of testing of this device on two subjects are also presented.

2. Materials and Methods

Each piece of the vibrotactile device is made entirely of non-ferromagnetic materials, completely compatible with the magnetic field of the MRI. The device is housed inside a piece of PVC tubing, functioning as the sole region of contact with the subject. A delrin rod runs along the main axis of the PVC tubing. This rod is connected to the device through two end caps constructed from nylon 6/6 stock. Within each endcap, a cylindrical hollow was made to allow for the insertion of acetal ball bearings that connect to the delrin rod Attached to the rod are two hollowed out computer fans and a semi-circular offset mass. Air from the compressor hits the fans through two small channels created through the circular end cap. One channel is angled at 45 degrees and the other at 60 degrees. Air comes in from these channels to hit the fans, providing sufficient rotational force to rotate the delrin rod, thus acting as a turbine. Figure 1 shows the assembled version of the assembled vibrotactile stimulator.

A control box with two valves was developed and regulation of the control box is facilitated via a laptop computer running SuperLab Pro (V2.04), which sends digital signals to the control box via an 18-pin IDE cable, enabling the control box valves to open and shut on command. Atmospheric air used as the working fluid is collected, stored and supplied by a Porter Cable brand compressor (150 PSI, 4.5 Gallon, oil-free). Atmospheric air travels from the compressor into the inlet of the control box. The design of the control of the stimulator is described in Figure 2.

3. fMRI Testing and Results

Two healthy volunteers (1 male, 1 female; both aged 33 years respectively, both right handed, with no known neurological or psychological pathologies) participated in this study. Informed consent was obtained from each subject, as detailed by the MNI ethics committee standards. Both anatomical and functional information was acquired using a Siemens 1.5T Magnetom Sonata system with an eight channel head coil. All subjects were immobilized using a vacuum bag and head holder assembly. A T1-weighted anatomical MRI (1 mm isotropic resolution) was acquired using a gradient-echo sequence as an anatomical reference for each subject (TR = 22ms, TE = 92ms, and a 30 degree flip angle). Functional data was acquired using a BOLD sequence (with a 64 x 64 x 64 image voxel matrix at 4mm isotropic resolution, TR = 3.5s, TE = 50 ms, 138 frames, 90 degree flip angle, total) acquired. Four separate runs of functional acquisition were performed, where each run required 8 min and 7 seconds.

During each run a simple block-design experiment used where the device remained off for the first 10 seconds of each scan, then oscillated for 15 seconds between the on and off phase, respectively, for a total of 16 repetitions. Each subject was scanned with the stimulator on the right side. All subjects were asked to grasp the stimulator firmly so that the maximum amount of somatic contact would be achieved. The stimulator was positioned at an angle of approximately 45 degrees relative to the ground, inclined towards the subject's head. The functional data was analyzed using the fmristat package developed by Worsley *et al.* [5]. Results shown in Figure 3 demonstrate significant activations of the somatosensory pathways in both individuals.

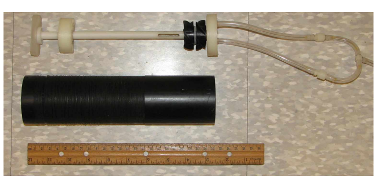

Figure 1. Vibrotactile simulator after construction

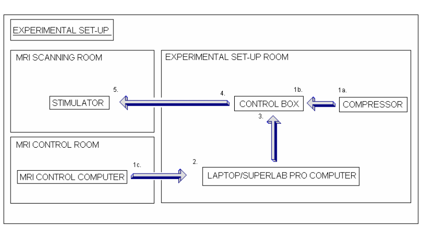

Figure 2. Control of Vibrotactile Stimulator. 1.) Primary start-up; 1a.) The compressor is turned on 1b.) Air flows from the compressor to the control box 1c.) The MRI Control Computer starts the scanning sequence, sending a signal to the laptop to begin SuperLab Pro. 2.) SuperLab Pro receives the MRI Control Computer start-up signal. 3.) The control box receives commands to open its internal valves at predetermined, times intervals. 4.) Compressor air flows through the control box on its way to the stimulator. 5.) The stimulator receives the compressed air.

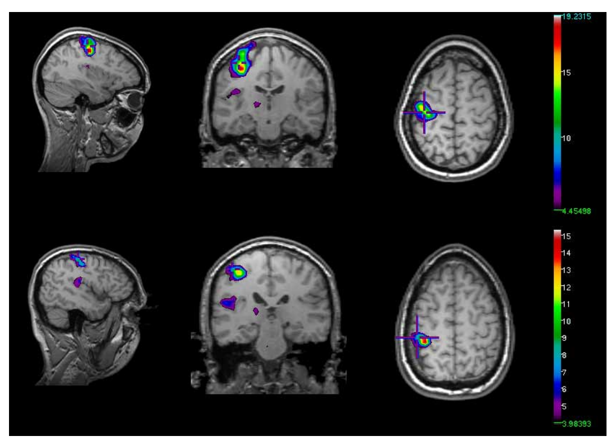

Figure 3. Results of fMRI experiment. Result from two subjects show significant activation of the somatosensory cortex, thalamus, and S2. **Left to right:** Sagittal, coronal, and axial views. **Top to Bottom:** Subject 1 and Subject 2.

References

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