A device for the parametric application of thermal and tactile stimulation during fMRI

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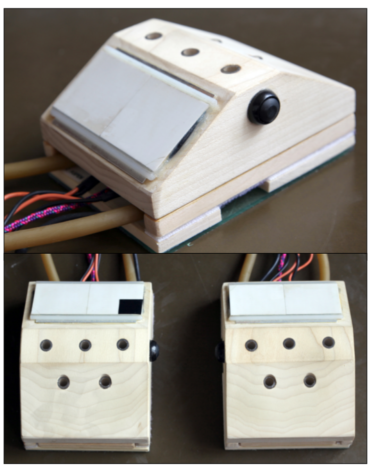
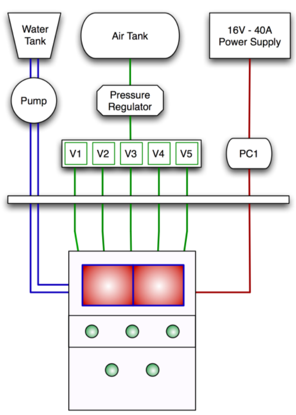
INTRODUCTION

While thermal and tactile stimulation have been investigated using functional neuroimaging a number of questions still exist regarding these basic perceptual processes. For example, studies investigating thermal changes have primarily examined stimulation applied to only one hand, yielding no knowledge related to differences in the laterality of thermoception [Craig, 1995; Hua, Strigo, 2005]. This is a fundamental question, as other studies have identified laterality differences in tactile stimuli [Coghill, Gilron, 2001]. Additionally, thermal and tactile changes have never been directly compared, resulting in little knowledge of how these systems are similar or different. In this poster we describe a new apparatus designed to apply parametrically-varied thermal and tactile stimulation to each hand independently. This apparatus was constructed with the intention of building event-related fMRI experiments to examine both independent and combined thermal and tactile stimuli.

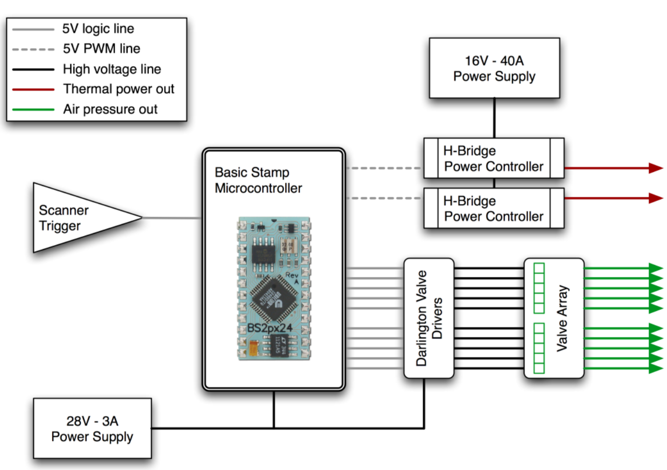
METHODS

The design of the apparatus involved the use of four Peltier-effect thermoelectric devices for thermal stimulation and ten pneumatically-driven wooden pegs for tactile stimulation. These elements were embedded within wood blocks designed to fit the contours of an average human hand (see below). Each hand block (one each left and right) contained two thermoelectric devices, five tactile stimulators, and one thumb button for responses. To enable the rapid application of large thermal changes each thermoelectric device was cooled with water pumped from the control room. Thermal and tactile stimulus application was controlled through the use of a programmable microcontroller. This control system enabled reliable millisecond timing for event-related stimulus application.





CONTROLLER SCHEMATIC

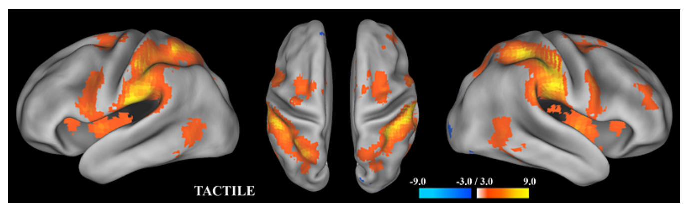


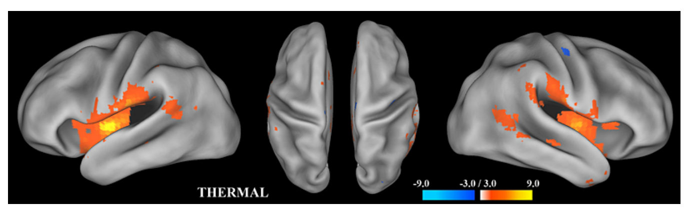
TESTING AND VALIDATION

Validation of the apparatus included onset time measurement, thermal range quantification, and noise/artifact testing within a MRI scanner suite. Using a computer-based data acquisition system the mean time for peg engagement was 192ms with a range of 185ms to 220ms. This was measured using a regulated 45 PSI air source. The mean time to achieve cold temperatures was 422ms with a range of 362ms to 470ms. The mean time to achieve hot temperatures was 351ms with a total range of 290ms to 398ms. The total thermal range of the thermoelectric devices was also quantified. Within 750ms the device temperature could reach approximately 130 degrees F at maximum and 25 degrees F at minimum. These parameters were used in the final device calibration to yield equivalent increases and decreases in temperature over time.

Twenty subjects participated in a validation fMRI study of the device. The experiment was set up as an event-related design with a principal factor of sensory modality [thermal and tactile]. Each subject completed one fMRI session consisting of twenty bilateral stimulation events of each condition. Each event lasted 650ms and had between 5.5s and 8.2s of rest between each event. Events were counterbalanced across the run to avoid order effects. Large blocks of rest lasting 15s were placed at the beginning, middle, and end of the task. Total scan time was 6 minutes. To reduce individual variability in thermal and tactile sensitivity each subject completed a thermal and tactile calibration procedure before participation

The fMRI results indicated that the apparatus could reliably activate areas of somatosensory and interoceptive cortex. The tactile figure below shows the pattern of activity generated during simultaneous left and right hand somatosensory stimulation. Bilateral regions of primary and secondary somatosensory cortex were observed to have increased activity. The thermal figure below shows the pattern of activity generated during simultaneous left and right hand thermal stimulation. Bilateral areas of secondary somatosensory cortex and posterior insula were observed to have increased activity.





CONCLUSIONS

The ability to directly contrast multiple sensory modalities during the acquisition of functional neuroimaging data is an important investigative tool for cognitive neuroscience. The device described in this abstract meets the experimental requirements to complete these investigations and the technical requirements to be placed inside of the MRI scanning suite. Adding the ability to stimulate each hand with a different parametric value adds flexibility of investigation. Additional studies are planned to explore factors such as laterality and parametric sensory response.

REFERENCES

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