An fMRI Study of Touching a Virtual Object Using a Data Glove with Tactile Feedback

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Introduction

Virtual reality (VR) technology holds promise for assessing and rehabilitating cognitive and sensorimotor function and, when combined with fMRI, enables exploration of the brain activity associated with complex behaviours. There is a related need for devices that are intuitively adopted by humans to interact in virtual environments (VEs), such that the resulting brain activity and behavior are representative of those in the real world. Towards the latter goal, an fMRI-compatible data glove with vibrotactile feedback was developed and initially tested in an fMRI study of touching a virtual object.

Materials and Methods

The experiment utilized an existing VR-fMRI platform [1] to implement a simple VE (Fig. 1a) consisting of a virtual block and a virtual human hand. The virtual hand was controlled via input from a custom-built data glove (Fig. 1b), which included a small magnetomechanical vibrotactile device (MVD) [2] attached to the index finger to deliver tactile stimuli whenever the virtual block was touched. Fourteen subjects (mean age = 26.5, right-handed, 11 male, 3 female) performed a series of blocked-design tasks during fMRI, including passive vibrotactile stimulation and active (touching) tasks [3] with and without tactile feedback. Data from two subjects were excluded from the fMRI analysis because they exhibited head movement > 1mm during the experiments. At the conclusion of the scans each subject was asked to complete a series of questionnaires [3] concerning their experience within the VE.

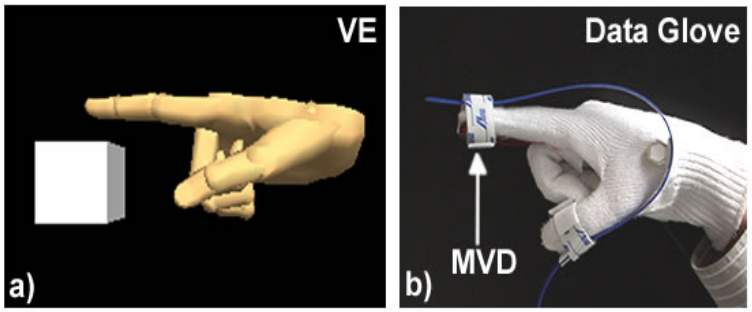

FIG. 1.

Results

Subjects experienced no difficulties performing the tasks. Behavioural data indicated that subjects penetrated the virtual block slightly further in touching tasks with tactile feedback than without (Fig. 2a, p=0.02). Subjective presence scores were also significantly greater (Fig. 2b, p=0.01) for touching tasks with tactile stimuli versus those without (passive and touch).

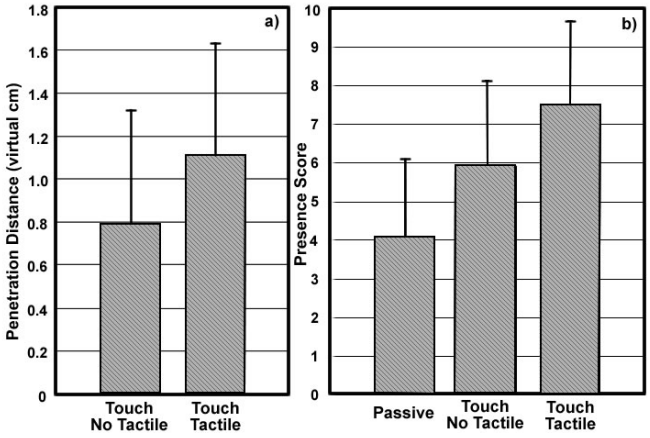

FIG. 2. Error bars represent the standard deviation.

A conjunction analysis was performed on the fMRI data to separate activity common across the tasks with regions that activated only during a select task. In addition to the expected motor and sensory regions, the left inferior and medial frontal gyri were active during both touching tasks (Fig. 3a). Increased brain activation was noticed in the right inferior and superior parietal lobule, the cingulate cortex, the left inferior frontal gyrus, the right precentral gyrus and the left insula during touching tasks with tactile feedback (Fig. 3b). The latter activations reflect multi-modal sensory integration as subjects attempted to link movements in the VE, observed visually, to tactile sensations delivered when the virtual block was touched.

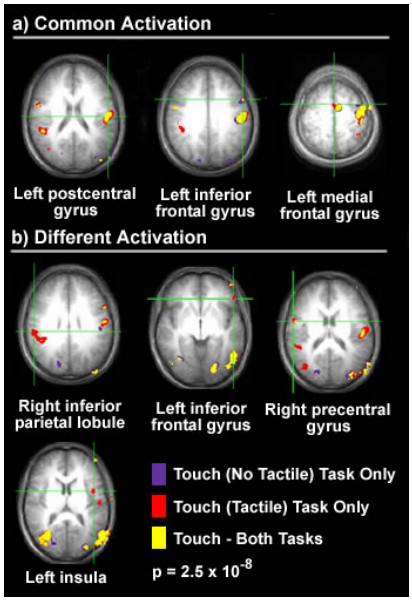

FIG. 3.

Conclusions

The fMRI-compatible data glove with tactile feedback enhances the realism during interactive tasks involving virtual objects. Future work will include further realism enhancements as well as application of the device to other VR-fMRI research areas, such as behavioural assessment in patients recovering from stroke.

References

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