An MR-Compatible Haptic Device for fMRI Investigations of Force Control

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Introduction

An MRI compatible haptic device was built to investigate human motor control. The device allows application of force and motion in one dimension to the index finger with the thumb kept fixed. Simultaneously, finger position and forces applied by the subject are recorded. The first application focused on the examination of brain areas involved in the control of manually applied forces.

Materials and Methods

16 healthy volunteers (10f, 6m, age: 26±4) participated in this study. A training session preceded the actual fMRI experiment. One session of the functional experiment consisted of 3 constant force, 3 simple varying force and 3 complex varying force field tasks in random succession. During each task two discs were presented. The challenge for the subject was to keep the smaller disc, which was moving in one dimension according to the applied force field, within the boundaries of the bigger. To accomplish this a counter-force had to be applied by moving the index finger towards or away from the thumb. The simple varying force field consisted of a sinusoidal force amplitude, to obtain a complex varying force field, several sine waves with different amplitudes and phases were added together. Each task had a duration of 20 seconds and was followed by a 20s rest period. One fMRI experiment consisted of 3 repeated sessions. All experiments were performed on a 3T headscanner (Allegra, Siemens Medical, Erlangen, Germany). An EPI sequence with the following parameters was used for functional imaging: TR= 2.5s, TE=32ms, voxel size: 2.5x2.5x2.5mm^3, 36 slices. FMRI data were evaluated in SPM5.

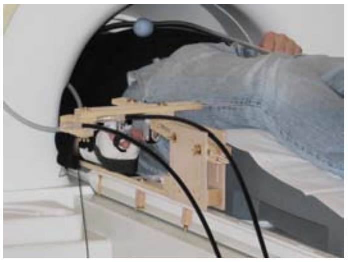

Fig. 1: *MRI compatible haptic device.*

Results

The hydraulically driven haptic device had no influence on MR data acquisition. Fig. 2 shows recorded force data for the three force fields used in this experiment. In our initial evaluation of the functional data these force data served as a control of the performance of the individual subjects. A group analysis of the functional data showed significant differences when comparing the response to simple or complex force fields to the response to the constant field (Fig. 3). Supplementary motor area (SMA), primary motor cortex (ipsi- and contralateral), frontal eye fields and the cerebellum exhibited stronger activation during application of the non-constant force fields. However, no important differences in activation were found when comparing responses to complex and simple varying force fields.

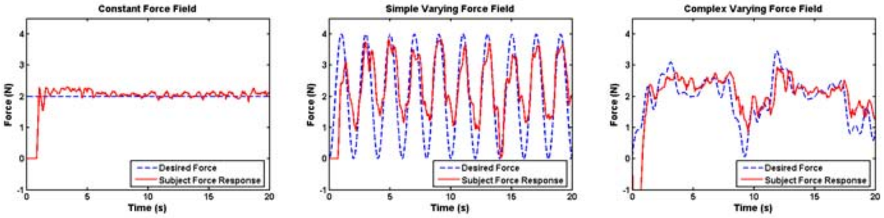

Fig. 2: *Recorded force data for 3 different force fields applied.*

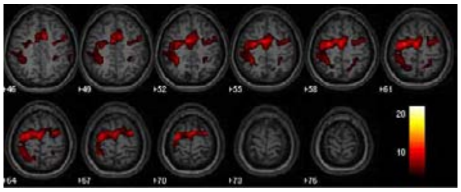

Fig. 3: *Brain areas that showed higher activation during the complex force task than during application of constant force.*

Discussion

The results of the present study demonstrate the feasibility of the home built device for functional MRI studies of the human motor system. Higher task difficulties have been shown to increase activation of cerebellum and ipsilateral motor cortex (1). In contrast to a study on movement predictability (2), no significant differences were found when comparing the complex (unpredictable) against the simple (predictable) varying condition in our experiment. It seems that the necessity of continuously changing the applied force even in the simple condition provokes stronger activation changes than the difference in predictability of the two tasks used in this study. Obtained activation changes in the frontal eye fields show that task presentation caused different visual activation for the different conditions and therefore has to be modified in future studies.

References

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