NEURAL CONTROL OF PLANTAR FLEXOR EXERTIONS: COMPARISON OF UNILATERAL AND BILATERAL EXERTIONS

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INTRODUCTION
With the advent of neuroimaging techniques such as functional magnetic resonance imaging (fMRI) it has become possible to determine areas of activity within the Central Nervous System during motor tasks. To date most of this work has focused on determining the mechanisms involved in the control of hand movements. The goal of this work was to determine which neural resources are involved in the control of plantarflexion movements of the ankle joint and compare the resources that are used in unilateral exertions to those that are used in bilateral exertions. We are particularly interested in which neural areas are involved in the coordination between the left and the right limbs. The findings of this work could be used to help improve our understanding of the neural mechanisms that are involved in the coordination of more complex lower-limb movements.

METHODS
Eleven healthy individuals volunteered to participate in this experiment (Age=19-34 years; 4M 7F). All participants were right handed and right foot dominant [1]. Participants attended a session where they practiced producing near isometric plantar flexor exertions at 15% of their Maximum Voluntary Contraction (MVC) on a custom made measurement system, in one of three conditions: with their right foot (R-ONLY), with their left foot (L-ONLY) or with both feet (BILAT). Participants were provided with visual feedback regarding the force they were producing in all conditions. During these exertions, the participant was supine, with their knees bolstered to a 90° angle. Electromyography was used over several lower-limb muscles to verify that the main plantar flexor exertion was the result of activity in the Soleus muscles.

In a separate session, fMRI data was obtained during while the participant performed the same task. The participants performed a total of 16 exertions in each condition. The order of the exertions was randomized, with a random period of time between 10s and 16s between each trial. The force produced during each trial was also recorded. An anatomical scan of the brain was also acquired for each participant.

The magnitude of the force produced by each participant was analyzed with a repeated measures ANOVA to determine if there were any differences in the force produced between the three conditions.

Standard fMRI processing techniques were used to create maps that identified regions of the brain that were active in each condition, for each participant. These were analyzed across the participants in two ways: a whole-brain analysis to identify the areas that are uniquely activated in the BILAT condition and using a regions of interest (ROI) approach, where comparisons in the magnitude of activation in motor regions of the brain were carried out between conditions.

RESULTS
Analysis of the magnitudes of the forces produced revealed that participants produced a statistically significant lower force with their left foot compared to their right foot. However, the mean difference between the two feet was less than 2% MVC.

The voxel-wise analysis of areas that showed significant activation in the BILAT condition compared to the two unilateral conditions resulted in 42 clusters being identified. These regions were distributed across motor, visual, sensory, and executive processing centres. Subcortical regions including the thalamus and the cerebellum were also identified as being uniquely activated in the BILAT condition. In all of the regions identified there was greater activation in the BILAT condition compared to the unilateral conditions.

The ROI analysis revealed that there was significantly higher activation in the BILAT condition when compared to the R-ONLY condition in the following motor areas: right primary sensory cortex, right ventral premotor cortex, dorsal premotor cortex bilaterally.

DISCUSSION & CONCLUSIONS
This study is the only study to date that compares neural activation within the CNS between tasks that were performed bilaterally to those performed unilaterally with the lower-limb. The primary finding of this study is that there is a vast network of neural resources that are required to coordinate movement between the left and right ankle joints.

Similar fMRI work, from upper-limb studies, has shown that the supplementary motor area (SMA) is primarily responsible for the coordination of bilateral movements [2]. However in this study of lower limb movements, there were no significant differences in activation between unilateral and bilateral exertions within the SMA and differences in motor areas were primarily limited to the premotor cortex.

REFERENCES

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