Differences observed in subcortical motor structures active during automatic and effortful movements

S. T. Witt[1], K. M. McMillan[2], M. E. Meyerand[1]

[1]Department of Medical Physics, University of Wisconsin, Madison, WI, United States, [2]Department of Radiology, University of Nashville, Nashville, TN, United States

INTRODUCTION

We present the first neuroimaging study examining the differences between the neural pathways involved in automatic movements and effortful movements in normal, healthy adults. FMRI activation maps collected from a group of healthy, right-handed adult subjects show that a dichotomy exists between the subcortical motor structures involved in automatic and effortful movements exists similar to that shown for internally generated movements and externally guided movements.

Several studies have examined the differences between the neural pathways involved in internally generated and externally guided movements. A functional dichotomy has been proposed in regards to the subcortical motor structures. The basal ganglia have been shown to be linked to internally generated movements, the cerebellum to externally guided movements. [1] More recent studies have demonstrated that the dichotomy is not as clear, since both subcortical motor structures have been shown to be active during both internally generated and externally guided movements. The structures may show a preferential activation to one or the other conditions. Additionally, the activation may be limited to a partial subcircuit of the structure depending on the condition. [2]

METHODS

Data were acquired on eleven healthy, right-handed adults on a 1.5T scanner (Signa LX; GE Medical Systems, Milwaukee, WI). A single-shot gradient-recalled echo-planar pulse sequence (TR/TE = 1750/40 msec) with FOV = 24 cm and a 64x64 matrix was used to acquire 23 axial slices (5mm/1mm) yielding whole brain coverage. All subjects gave informed consent, and all successfully completed the study. FMRI data was collected for two bimanual finger tapping tasks; each task consisted of alternating 20 second blocks of rest and tapping and lasted for 3 minutes and 40 seconds. The finger tapping tasks were: (1) tapping both index fingers, simultaneously, at a comfortable pace and (2) tapping both index fingers, simultaneously, emphasizing the down stroke of the tap (i.e. tapping hard). The former of the two tasks was designed to elicit automatic movement on the part of the subject, while the latter of the two tasks, effortful movement.

Data for each subject were corrected for motion, normalized to the ICBM template, smoothed with an 8 mm FWHM Gaussian, and processed using SPM2 (Wellcome Department of Cognitive Neurology, London, UK). A group activation map was calculated for each task using SPM2. Maps are thresholded and corrected for multiple comparisons at $p < 1 \times 10^{-7}$.

RESULTS

Figure 1 shows the results for the two tapping tasks, illustrating the differences in the activation of the basal ganglia and cerebellum during the automatic and effortful tasks. During the first tapping task (Figure 1.A), there is clear bilateral activation of the putamen. During the effortful tapping task (Figure 1.B) there is still bilateral activation in the basal ganglia, but it is centered more on the Globus pallidus external as opposed to the putamen. During the automatic (Figure 1.C) task, there is bilateral activation in the cerebellum in the region of the dentate nuclei. The dentate nuclei have been shown to be involved in the timing and coordination of upper limb movements. There is much more diffuse, bilateral activation of the cerebellum seen during the effortful tapping task (Figure 1.D). This result taken in conjunction with the apparent lack of bilateral activation of the putamen during the effortful tasks suggests that our initial hypothesis is correct. The basal ganglia, in particular the putamen, are preferentially active during automatic tasks, while the cerebellum is preferentially activated during effortful tasks.

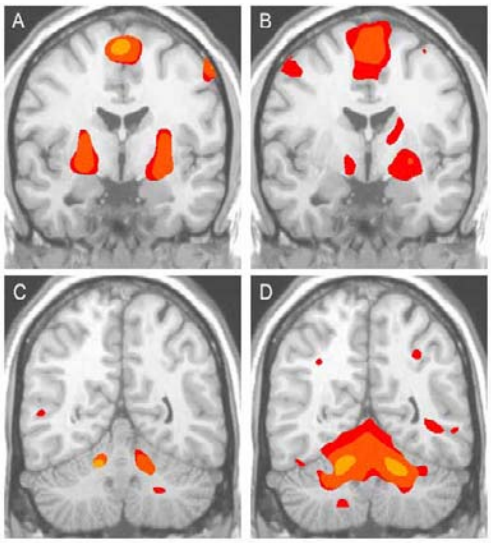

Figure 1: The results of group analysis for the automatic and effortful tapping tasks. (A) Automatic task ($p < 0.005$, $y = 3.5$); (B) Effortful task ($p < 0.005$, $y = 3.5$); (C) Automatic task ($p < 0.005$, $y = 56$); (D) Effortful task ($p < 0.005$, $y = 56$).

CONCLUSIONS

The results from the group functional maps support our hypothesis that as with internally generated and externally guided movements, there exists a dichotomy between the subcortical motor structures involved in automatic and effortful movements. The results have the potential to address aspects of Parkinson's disease such as the phenomenon of paradoxical movements.

REFERENCES

[1] Jueptner M and Weiller C. *Brain* 1998; 121: 1437-1449.
[2] Debaere F et al. *NeuroImage*, 2003; 19: 764-776.