Differential involvement of the striatum in the control of sequential movement complexity

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Introduction. Anatomical studies in non-human primates have shown that cortico-striatal connections are organized in segregated circuits (1). Electrophysiological studies in primates have shown that these circuits are differentially involved in the control of movement. Thus, areas subserving movement execution are caudal to areas involved in movement preparation (2,3) or in higher order cognitive processes such as working memory (4). In humans, PET studies have shown activation increase in premotor and parietal areas during sequences of finger movements with increasing sequence complexity (5,6). We tested the hypothesis that simple sequence of movement would recruit the anterior putamen, whereas more complex sequence would recruit more anterior parts of the striatum including the caudate nucleus.

Materiel and methods. Eight healthy right-handed volunteers were studied with EPI BOLD contrast at 3T. 28 single shot EPI axial slices were obtained using the following parameters: TR/TE/angle: 3s/40ms/90°, in plane resolution: 1.5x1.5 mm^2, slice thickness 2.5 mm, no gap, 140 acquisitions. Tasks consisted of 3 conditions of sequential key press on a keyboard using fingers 2 to 5 of the right hand (5): 1) Simple repetitive index finger tapping; 2) Scale finger tapping (from 2 to 5); 3) Complex sequence of 10 moves long. Tasks alternated with rest every 21 sec during 10 epochs. Tasks were pseudo-randomly ordered across series. Movements were audio-paced at 1 Hz. Before scanning, all subjects practiced the complex sequence until they could perform it from memory 10 times in a row without error. Individual analysis and random effect group analysis were performed using SPM99. Activated clusters were considered significant at $p<0.05$ corrected for multiple comparison within the volume of the whole brain in the cortex and of the striatum in the basal ganglia.

Results. In all tasks, activation was found in the contralateral primary sensorimotor cortex (SMC), secondary sensory area (SII), and posterior part of the putamen (Fig. 1). Bilateral preSMA, lateral premotor (PM), associative parietal areas, anterior putamen, and caudate nuclei were recruited during the complex sequence. The Scale-Simple comparison showed activation in the contralateral SMC, SII, parietal (BA 7), anterior putamen, and bilateral caudate nuclei (Fig. 1). The Complex-Scale comparison showed activation in bilateral PM, parietal (BA7,40), precuneus and caudate nuclei (Fig. 1). The cerebellum was not included in the imaged volume. Regression analysis showed that increased movement complexity resulted in increased activation in the left SMC, SMA, precuneus, and anterior putamen, the right preSMA, and bilateral associative parietal and PM areas, caudate nuclei, and thalami.

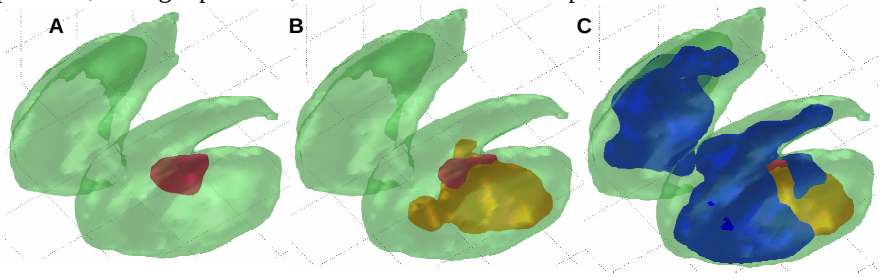

Figure 1. Striatal activation during the simple (red, images A to C), scale (yellow, images B and C) and complex tasks (blue, image C) viewed in a transparent 3D reconstruction of the striatum. Anterior is left.

Conclusion. These data suggest that each striatal compartment has specific role in the control of movement complexity and sequencing. The posterior part of the putamen was activated during all movements. Simple sequencing induced recruitment of the anterior putamen, and the complex sequence task was associated with further recruitment of bilateral caudate nuclei.

References. (1) Alexander GE et al. Prog Brain Res. 1990;85:119-46. (2) Alexander and Crutcher, J Neurophysiol. 1990;64:133-150. (3) Schultz and Romo, Exp Brain Res 1992;91:363-384. (4) Hikosaka et al. J Neurophysiol. 1989;61:780-798. (5) Catalan et al. Brain 1998; 121: 253–64. (6) Boecker et al. J Neurophysiol. 1998;79:1070-1080.

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