Functional subdivision of corticostriatal interconnections visualized by fMRI

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Introduction

Cortico-striato-thalamo-cortical interconnections are thought to be organized in anatomically and functionally segregated loops. The tripartite model proposes their division into pure motor, associative and limbic portions. In analogy, anatomical studies revealed subdivision of the involved brain structures: in cortex and striatum pure motor areas are located posterior to associative areas. Functional imaging of the distinct circuits has been attempted, mostly by varying motor characteristics known to be specific for one of the circuits. However, a functional mapping of corticostriatal projections is still lacking.

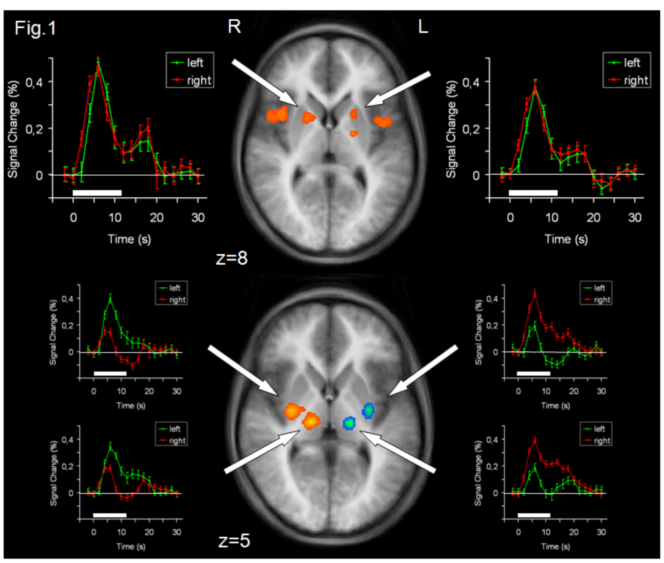
Methods

A blocked-designed paradigm was tested in 26 healthy right-handed 10-15 year-old boys using fMRI. 8 alterations of motor condition (12s) and rest condition (18s) were performed with either hand separately: unilateral index finger tapping was conducted in a self-paced manner. Imaging was performed at 3T (Magnetom Trio, Siemens) using the standard 8 channel phased array head coil. A T1 dataset was acquired at 1 mm^3 isotropic resolution (3D Turbo FLASH). Functional imaging was performed using a T2*-sensitive gradient-echo EPI technique with an in-plane resolution of 2 x 2 mm^2 (TR 2000 ms, TE 36 ms, flip angle 70°, acquisition matrix 96 x 128). 129 EPI volumes of 22 sections at 4 mm thickness angulated in an axial-to-coronal-orientation were acquired.

Functional data were preprocessed and coregistered to the T1 dataset, which was then transformed into Talairach space. Main effects were calculated for each hand (movement vs rest). A conjunction analysis was conducted to identify regions involved in both, right and left unimanual movement; a contrast analysis allowed identification of brain regions involved side specifically.

Results

Main effects showed mirror inverted activation maps for either hand movement. Bilaterally activated regions were SMA (supplementary motor area), pre-SMA, striatum and insula. Sensorimotor cortex (SMC) and thalamus were only activated contralaterally to the moved hand, cerebellum ipsilaterally. The conjunction analysis revealed involvement of anterior SMA, pre-SMA, anterior striatum and median cerebellar parts in both right and left unimanual movement. Contrast analysis showed side dominance for posterior SMA, SMC, posterior striatum as well as for lateral cerebellar parts.



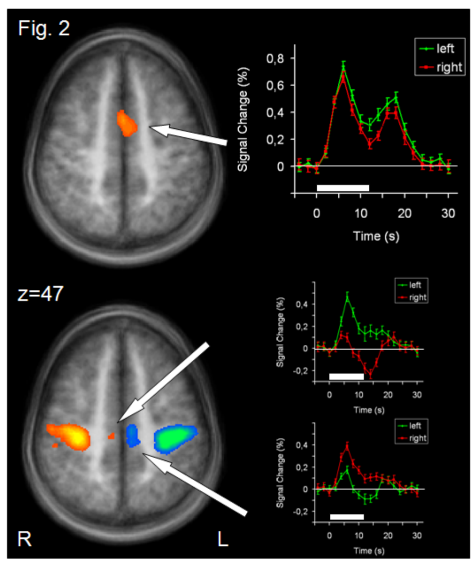


Fig. 1: Conjunction analysis (top) and contrast analysis (bottom) of basal ganglia and thalamus. Time courses are displayed for the labelled structures. The white bars indicate the interval of the movement condition. $p<0.001$; corrected for multiple comparisons.

Fig. 2: Conjunction analysis (top) and contrast analysis (bottom) of SMA/pre-SMA. $p<0.001$, uncorrected.

Discussion

We provide in-vivo visualization of two human cortico-striato-thalamo-cortical circuits. Coactivation of anterior SMA, pre-SMA and anterior striatum during both right and left hand movement suggest their belonging to associative parts of the corticostriatal interconnections. This seems plausible as the self-paced task demands motor planning and timing functions. SMC, posterior SMA, posterior striatum and thalamus, however, would be part of the sensorimotor circuit, mainly involved in purely motor, executive tasks. This is supported by their clear side specific, somatotopic activation pattern. Analogously, previous functional imaging studies have shown that manipulation of task complexity influences anterior parts of SMA and striatum, possibly part of the associative loop, whereas purely executive task characteristics modify posterior striatum and SMC. Furthermore, a meta-analysis of 126 functional imaging studies described coactivation of pre-SMA, anterior striatum and median cerebellar parts on the one hand and SMC, posterior SMA and lateral cerebellar parts on the other hand. Our findings thus support concepts on functional subdivision of corticostriatal interconnections and provide a new in-vivo functional mapping of the pure motor and the associative circuit.

References: 1. Alexander, G. E. et al. (1986). Annu Rev Neurosci 9: 357-81. 2. Boecker, H. et al. (1998). J Neurophysiol 79(2): 1070-80. 3. Lehericy, S., E. et al. (2006). Cereb Cortex 16(2): 149-61. 4. Postuma, R. B. and A. Dagher (2006). Cereb Cortex 16(10): 1508-21.