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RESEARCH ARTICLE

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The sensory guidance of movement: a comparison of the cerebellum and basal ganglia

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Abstract We used positron emission tomography (PET) to compare the contribution of the cerebellum and basal ganglia to the sensory guidance of movement. In one condition the subjects used a computer mouse to draw a series of lines on a computer screen (DRAW). In the second condition the same lines were presented to the subjects, and they had to track the lines with a mouse pointer on the screen (COPY). In a third condition the subjects were again presented with the same lines, and they simply followed movements of the pointer with their eyes (EYES). In the fourth condition, the subjects fixated a central point, ignoring the sequence of presented lines (FIX). The pons and cerebellum were activated more during visually guided tracking than in freely generated drawing (COPY vs DRAW). The basal ganglia were activated equally in both DRAW and COPY. The prefrontal and inferior temporal cortex were activated more when subjects drew lines freely (DRAW) than when they copied them (COPY). We conclude that the cerebellum is specialized for using sensory information to correct movements, but that the basal ganglia are involved both in movements that are self-generated and in movements that are guided by external cues.

Key words Positron emission tomography · Basal ganglia · Cerebellum · Prefrontal cortex · Parietal cortex

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Introduction

Sensory cues act to instruct animals what to do, to tell them when to do it, and to guide continuous movements. In previous papers we have compared acts that are self-generated or selected on the basis of external cues (Deiber et al. 1991; Frith et al. 1991), and acts that are self-initiated or paced by external cues (Jahanshahi et al. 1995). In the present paper we consider the sensory guidance of continuous movement.

The main aim of the experiment was to compare the roles of the basal ganglia and cerebellum. Both structures receive information from sensory, motor and association cortices. They appear to differ, though, in the areas from which they receive visual and somatosensory information. The cerebellum receives visual inputs via the pons from areas in the dorsal visual system, including area V5 and parietal area 7 (Ungerleider et al. 1984; Schmahmann and Pandya 1991). However, the inputs from the temporal lobe appear to originate mainly in the polysensory cortex in the upper bank of the superior temporal sulcus (Schmahmann and Pandya 1989, 1991), and this region is closely interconnected with parietal area 7 (Seltzer and Pandya 1994). The striatum receives an input from both temporal and parietal association areas (Selemon and Goldman-Rakic 1985). However, unlike the cerebellum the striatum receives heavy projections from the convexity cortex of the temporal lobe, including the inferior temporal cortex (areas 21, 20) (van Hoesen et al. 1981; Selemon and Goldman-Rakic 1985; Saint-Cyr et al. 1990).

It has been suggested that the projections to the pons from pariental area 7 and area V5 carry information about visual location and motion (Stein and Glickstein 1992). Information of this sort is essential for the visual guidance of movement.

Somatosensory (proprioceptive) information from muscle spindles and tendon receptors is conveyed to the cerebellum via the climbing and mossy fibre systems; these afferents mainly provide the cerebellum with information about joint position (Murphy et al. 1973; Baus-