Separated Modules for Visuomotor Control and Learning in the Cerebellum: A Functional MRI Study

Hiroshi Imamizu[1], Satoru Miyauchi[2], Yuka Sasaki[2], Ryousuke Takino[3], Benno Pütz[1] and Mitsuo Kawato[1,4]

[1] *Kawato Dynamic Brain Project, Japan Science and Technology Corporation, Kyoto, Japan;* [2] *Communications Research Laboratory, Tokyo, Japan;* [3] *Shiraume Gakuen College, Tokyo, Japan;* [4] *ATR Human Information Processing Research Laboratories, Kyoto, Japan*

Many studies have suggested that the cerebellum is involved in the smooth and rapid control of limbs (1). Furthermore, the involvement of the cerebellum in visuomotor learning was demonstrated by neurophysiological and fMRI studies (2,3). In this study, we conducted two experiments to identify the locus of visuomotor control and that of learning in the cerebellum and to examine whether these loci are different from each other.

Subjects and Methods: Three subjects, aged 19-28 years, participated in both experiments. In the first experiment, we tried to find the locus of visuomotor control. The subjects executed a "tracking task" during the test periods. The task was to manipulate a computer mouse with the right hand so that the corresponding cursor would follow a randomly moving target on the screen. The mouse orientation was adjusted so that the cursor on the screen and the mouse would move in almost the same direction. Before the beginning of the experiment, the subjects were allowed to practice the tracking task until they could easily perform the task. The subjects pursued the same target using their eyes but without hand movements during the baseline periods. This paradigm is expected to extract activities related to the visuomotor control of limb movements from other activities, e.g. those related to control of eye movement. In the second experiment, we tried to find the locus of visuomotor learning. The subjects executed the tracking task during the test and baseline periods. The cursor position, however, was altered by a 120˚ rotational transformation during the test periods to necessitate the visuomotor learning. The distance between the target and the cursor was named "tracking error" and was used to evaluate the subjects' performance. The experiments were carried out with a 1.5 T Siemens scanner equipped with an EPI booster. Functional images were acquired from axial plane containing the cerebellum (5-7 mm thick, TR = 4 s, TE = 66 ms, FA = 90˚, FoV = 220 mm by 220 mm, matrix = 128 by 128.) and analyzed by a cross correlation calculation for each pixel (4) to find significant activities (p<0.005).

Results and Discussion: In the first experiment, activities were observed in the anterior and posterior intermediate zone of the ipsilateral cerebellum (Fig. 1A). In the second experiment, the tracking error was larger during the test periods than that during the baseline periods. However, the error decreased and became almost the same as that during the baseline periods after two hours practice. In the early stage of the learning, activities were observed in the lateral part of the cerebellum on both sides (Fig. 1B). In contrast, the area became smaller in the late stage of learning, although activities were observed in almost the same loci as in the early stage of learning. The decrease in activities after practice is consistent with the results of a previous fMRI study (3). Our results suggest that the anterior and posterior intermediate zone is involved in the control of limbs and familiar apparatuses while the lateral zone of the cerebellum is involved in the learning of unfamiliar visuomotor environments.

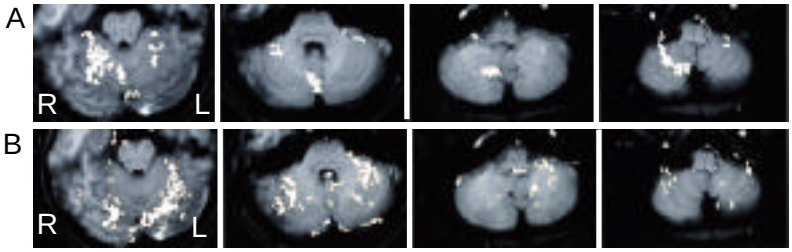

Figure. 1 Axial images of the cerebellum with superimposed activated areas in the first experiment (A) and the second experiment (B). The images are in superior (left) - inferior (right) order.

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