# Real-Time Assessment of Explicit Motor Sequence Learning by Functional MRI


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## Introduction

Recent studies have shown that visual-guided explicit motor sequence learning occurs in two stages. The first stage is the acquisition of visuo-motor associations, which is related to the activation in pre-SMA, and the next stage is the acquisition of the whole sequence, which is related to the activation in the precuneus, superior parietal lobules, SMA proper, and basal ganglia [1,2]. In order to enable prediction of the task performance in clinical diagnosis, a fully real-time analysis system using a PC cluster [3] was applied to evaluate the brain activities during explicit motor sequence learning task. Instead of repeating scan sessions and wasting long time for data analysis computation, the learning task was evaluated in a 10 minutes observation window. The questions were: does the activation in these areas predict the behavioral conditions and is the real-time fMRI system employed for data analysis applicable for clinical use?

## Methods

Subjects: sixteen volunteers (five males, age 22-39, all right-handed), who gave written informed consent, participated in this study.
Paradigm: The subjects were scanned during explicit learning as they performed a SRTT. A standard block design with ten control and ten learning blocks was used (30 sec/-each block). The subjects were instructed to press as quickly as possible and with minimal errors one of the four buttons corresponding to the location of the red cross that appeared above one of the four blue squares (modified version of the J. Doyon et al [4], Fig. 1.). The stimuli were presented either in an unpredictable order (control condition) or followed a repeating 6-item sequence of movements (learning condition). Before the scan, the subjects were explicitly informed about the existence of a repeating 6-item sequence of movements in learning condition, but the order was not revealed. They were asked to report the sequence after the scan.
Data Acquisition and Analysis: The real-time system was composed of an MR scanner subsystem (GE Signa VH/I 3.0T) and an attached computational server, a PC cluster composed of 8 dual-processor 800MHz PIII PCs with 1GB of memory running the Score Cluster System software [3]. A gradient-recalled EPI technique was used for the fMRI acquisition. The parameters were: TR 2000ms, TE 30ms, FA 90deg, matrix 64x64, FOV 220mm, slice thickness 3mm, gap 1mm. Thirty axial slices were obtained. Statistical analysis uses General Linear Model. The activation maps were generated with a height threshold of $p = 0.001$ for each experiment. Signal intensity changes ($\Delta$SI) in the pre-SMA and precuneus were measured after the scan. $\Delta$SI was calculated as: [(mean signal intensity in the 10 learning blocks) – (mean signal intensity in the 10 control blocks)] / (mean signal intensity in the 10 control blocks).

## Results

Performance data: The reaction time (RT) was decreased according to the procedure learned. However, the reduction rate of the RT varied among the subjects (mean 25.9, S.D. 11.0). There were no significant differences between the number of errors during the control and learning conditions in all subjects ($\alpha = 0.05$). One subject could not reproduce the correct order of the finger movement sequence after the scan session.
General activation: Significant activation were observed in the pre-SMA, prefrontal cortex, premotor cortex, intraparietal sulcus / posterior parietal lobe, and the precuneus during the learning condition. A representative image at the fronto-parietal level is shown in Fig. 2.
Activation time course: There was a significant correlation between $\Delta$SI and relative shortening of the RT in the precuneus (Fig.3A). The same correlation was not seen in the pre-SMA, although the two subjects with low performance show no activation (Fig.3B).

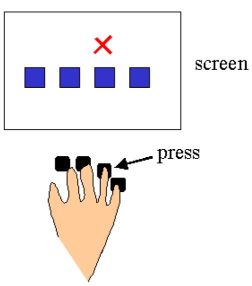


Fig. 1

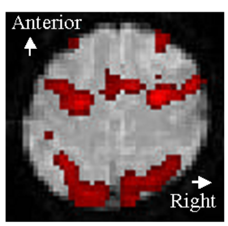


Fig. 2

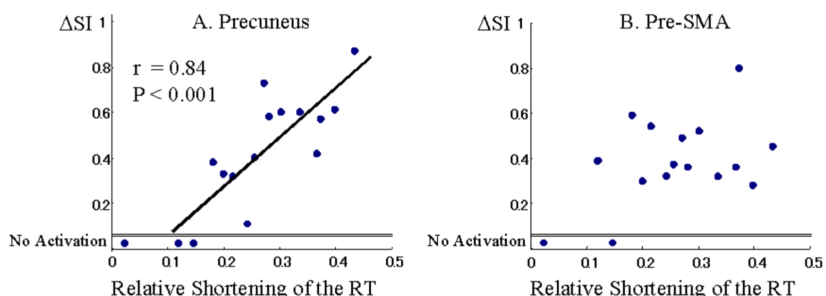


Fig. 3

## Discussion

We found a significant correlation between the $\Delta$SI and the relative shortening of the RT in the precuneus, which is known to play a critical role in the storage of spatial information for limb movement and memory recall. The $\Delta$SI in the precuneus may reflect the retention and recall of the motor sequence in the explicit SRTT. The reason we could not find such correlation in the pre-SMA may be that the memory retention and recall were more important for the RT shortening than the memory input related to the pre-SMA function. $\Delta$SI could be calculated simultaneously with the statistics during the scan, demonstrating the clinical utility of the real-time fMRI system in the evaluation of explicit motor sequence learning function. Patients with regional blood flow and metabolism reduction in the precuneus, such as mild cognitive impairment or early stage Alzheimer disease, can be evaluated by the real-time measurement of the $\Delta$SI in the precuneus for early diagnosis and assessment of disease severity.

## References


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