Investigating Motor Plasticity using Resting State fMRI and SEM

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INTRODUCTION

Motor plasticity studies performed so far focused on task performance data. Alternative to task performance, resting state shows more and more potentials in characterizing brain recently. To date, how long-term motor training affects resting state brain is still unclear. In the present study, we investigated motor plasticity by examining changes in resting state brain. In parallel to our previous task performance study [1], we explored changes in regional activity and inter-regional connectivity in the motor system resting state network (RSN).

METHODS

Ten normal subjects were trained to perform the Karni finger movement task [2] for 4 weeks. Three sets of resting state fMRI images (400 volumes, 7-slice with 72 × 72 voxels, TR = 700 ms, TE = 45 ms, flip angle (α) = 70°, slice thickness = 6 mm, interslice gap = 0 mm) were acquired at pre-training, Week 2, and Week 4. Independent component analysis was used to detect RSNs. A joint strength measurement (JSM), which was defined as the integration of the intensity over an activation focus, was used to measure the strength of regional activity within the motor system RSN. Effective connectivity was used to quantify the inter-regional connectivity, and structural equation modeling (SEM) was used as a system level modeling to evaluate the effective connectivity. Based on our previous work on task performance data [1] and the SEM model of motor execution reported by [3], we constructed and tested one SEM model that encompassed M1, SMA, dorsal premotor cortex (PMd), and posterior ventrolateral prefrontal cortex (pVLPFC).

RESULTS

Statistical analysis revealed that the subjects' skill improved much more significantly in the first half of training than in the second half. The rate improvement reached a plateau at about Day 20. The JSMs of M1&S1 and SMA regions across the three test periods are shown in Figure 1. For both regions, the mean JSMs increased from pre-practice to Week 2, but returned to baseline levels on Week 4. The SEM model fitted the three sets of data simultaneously. Figure 2 depicts the path coefficients of the SEM model across the three test periods. An omnibus test using a stacked model approach showed that the model at different testing times was significantly different from each other. Significant changes occurred in most of the path coefficients as motor training progressed (using stacked model approach). Three path coefficients significantly increased (M1→SMA, PMd→PFC) or decreased (PFC→SMA) from pre-training to Week 2. But the changes in the second half of training did not reach the statistical threshold. One path coefficient (PMd→M1) did not significantly change in the first two weeks. But it significantly increased from Week 2 to Week 4. Four path coefficients (PFC→M1, SMA→M1, SMA→PFC, SMA→PMd) increased then decreased (both significantly).

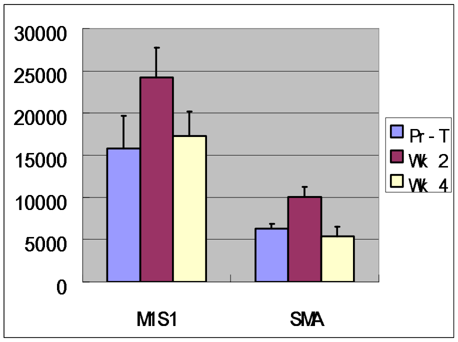

Figure 1: Changes of two regions of interest (ROIs) in the motor system RSN as training progressed. The x-axis corresponds to the two ROIs, and the y-axes correspond to JSM. Each bar represents a mean and each error bar represents a standard error. Pr-T and Wk 2 denotes pre-training and Week 2 respectively.

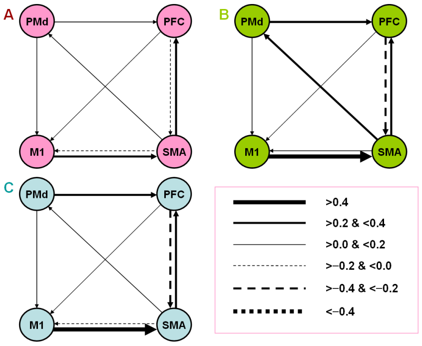

Figure 2: The SEM model at pre-training, Week 2, and Week 4. Different types of lines were used to provide rough information of path coefficients. PMd = dorsal premotor cortex, PFC = posterior ventrolateral prefrontal cortex.

CONCLUSION

In our previous task performance study [1], we observed increased-then-decreased mode of changes in regional activities. The same pattern of changes has been replicated by the resting state regional activity analysis. The changes in regional activity may reflect altered processing load during different phases of motor learning. During task performance, the inter-regional connectivity was strengthened as a function of motor learning [1]. Different mode of changes was observed in resting state inter-regional connectivity. Three path coefficients first increased (or decreased) then hold; one first hold then increased. Importantly, four path coefficients first increased then decreased, this mode of changes is similar to the operation procedure of memory consolidation (extensively operative during the early stage of learning, and less operative after the task becomes automatic) in skill learning. Because memory consolidation is one of the major functions of RSN, in addition, memory consolidation is also a major outcome of skill learning, we speculate that resting state inter-regional connectivity is associated with memory consolidation. Further experiments are needed to test this hypothesis.

REFERENCE

1. Ma, L, Wang, B, Narayana, S, Hazeltine, E, Chen, X, Fox, PT and Xiong, J, 2007. Motor Plasticity: An Investigation using Functional MRI and Structural Equation Modeling. Abstract in ISMRM) 2007.
2. Karni, A, Meyer G, Jezzard, P, Adams, MM, Turner, R and Ungerleider, LG, 1995. Nature 377, 155–158.
3. Solodkin, A, Hlustik, P, Chen, EE, Small, SL, 2004. Cerebral Cortex 14: 1246–1255.
4. Hazeltine, E, Grafton, ST and Ivry, R, 1997. Brain 120, 123–140.