Differential Consolidation of Motor Memory

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INTRODUCTION: There has been much interest in studying effects of training and how and where its footprint is retained in a resting brain (1-4). Many studies showed that the strength of functional connection between nodes in a brain can be modulated across varying time scale. However, none has compared how slight variation in the training training could alter the footprint pattern.

Our previous study compared fcMRI data before and after a 23-min button-press motor training and showed that cross-correlation coefficient (CC) and amplitude of low-frequency fluctuation (ALFF) in the bilateral motor cortices revealed a significant increase. The training in the previous study was a right-hand only button-press. Since it is known that bilateral finger movements resulted in a different pattern of neural activity compared to a unilateral movement (7), we hypothesize that the training-related modification due to a bilateral training should also be different from that after a unilateral training. To address this, we recruited two groups of subjects (n=24 in each group) and applied one-hand training and two-hand training, respectively. We compared pre- and post-training fcMRI data for each training group, and characterized spatial differences in the footprint patterns.

METHODS: BOLD fMRI data (3.4x3.4x5mm^3 voxels, TE 25ms, TR 1000ms) were acquired using a 3T Philips MR scanner. Healthy *right-handed* adults were recruited for either one-hand (n=24, 25±14y.o., 13 male) or two-hand studies (n=24, 30±10y.o., 9 male). The scan session included the pre-training fcMRI scan (under resting state), followed by the training, and then concluded with a post-training fcMRI scan. During the 23 minute training period, the subject performed either unilateral or bilateral motor training, in which they fixated on a white crosshair and, when the crosshair occasionally changed color to grey for 1000ms, they are supposed to press a button three times with their index finger (right-hand only for the one-hand training group and both hands for the two-hand training group) as soon as they saw the crosshair dim. The color change occurs every 27-32 seconds with randomized intervals. The two fcMRI runs before and after the motor training were performed with identical protocols (fixation on a white crosshair, 21 axial slices). The fcMRI scans were five minutes in duration. Post-processing: All images were co-registered to the first image volume of the first fcMRI run. Images were normalized to the TT_avg152 template in Talairach space provided by the Analysis of Functional NeuroImages (AFNI) software package. After low-pass filtering (< 1Hz), correcting for motion and respiration, and baseline level, the temporal signal remained is considered to reflect the resting state brain activity (to some extent). ALFF of each voxel timeseries is calculated as standard deviation/baseline*100. Voxel-wise interhemispheric correlation was calculated as the Pearson Correlation Coefficient of a voxel timeseries with that of its counterpart in the opposite side of the brain. Then paired-wise t-test was performed between pre-training and post-training resting state parametric maps. A FDR corrected threshold of P=0.01 and cluster size of 1350 mm^3 were applied on the statistical maps.

RESULTS and DISCUSSION: Figure 1 highlights voxels that showed a significant increase in ALFF in post-training fcMRI as compared to the pre-training data. The upper panel shows results from the one-hand group and the lower panel is from the two-hand group. Changes were observed in certain regions for both trainings. Regions unique to post one-hand training fcMRI include primary motor cortex (M1), supplementary motor area (SMA), and premotor area. Regions unique to post-two-hand training fcMRI include frontal lobe and basal ganglia. Regions common to both include posterior cingulate, precuneus, temporal and occipital lobes, auditory cortex and thalamus and cingulate gyrus.

We also examined whether there was a change in interhemispheric correlation comparing pre- to post-training fcMRI data. Figure 2 highlights voxels that showed a significant increase in the interhemispheric CC in post-training as compared to pre-training. One-hand training resulted in an increase M1, SMA, and primary somatosensory area (Fig. 2A). On the other hand, no changes were observed following the two-hand training (Fig. 2B). No regions manifested a decrease in CC (in either one-hand or two-hand group).

ALFF reflects amount of spontaneous fluctuation while CC measures the synchrony thereof. CC increased after one-hand training but not two-hand training. ALFF increased after both types of training, but their patterns are strikingly different. We believe this suggests our brain encodes these trainings differently. Unlike one-hand training, when two hands were involved, the encoding of training no longer took place in the motor and sensory areas; rather, it was transferred to frontal lobe, possibly involving mid-brain regions such as thalamus and basal ganglia, as basal ganglia is known to coordinate and regulate intensity in motor activities via relays through thalamus.

Even though our conclusion is based on a limited regime of finger moving training, the striking difference in selectivity for training encoding suggests that during rest, our brain is dynamically modulating the retention and transfer of this memory based on the amount of neural activities involved during training.

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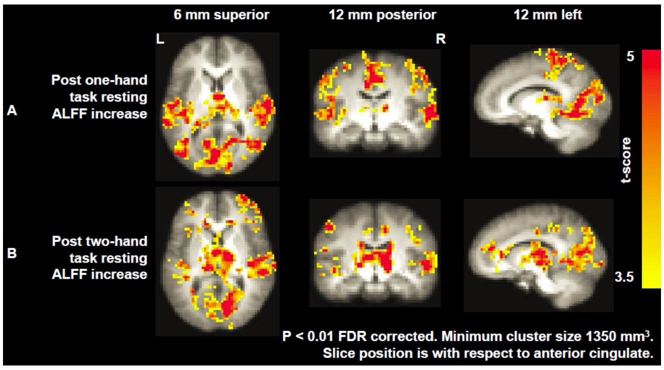

Figure 1. Voxel based map of increase in resting state ALFF after training. (A) Brain regions with increased ALFF after one-hand training, and (B) after two-hand-training. 3x3x3mm^3 voxel size.

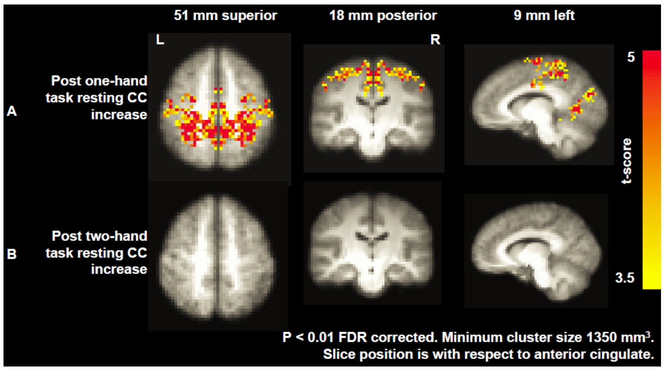

Figure 2. Voxel based map of increase in resting state interhemispheric correlation after training. (A) Brain regions with increased CC after one-hand training, and (B) after two-hand training. 3x3x3mm^3 voxel size.