Transient Neural Plasticity in Human Motor Cortex

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INTRODUCTION: Brain's plasticity forms the basis of many of our daily functions including memory and learning. It is then intuitive to speculate that certain changes have occurred to the brain comparing before and after the training/learning. However, the exact neuronal processes that are altered are poorly understood, especially for human studies in which available tools are limited. Recent studied have provided early evidences that it may be possible to identify such changes using MRI. Tzur-Moryosef and colleagues reported that water diffusion parameters in the rat cortex, e.g. FA and ADC, showed a decrease as a result of 3-hour Morris–water-maze training (1). We have previously shown that functional connectivity, measured as the cross-correlation coefficient (CC) between the left and right motor cortices in functional connectivity MRI (fcMRI), can be enhanced after merely 23 minutes of button press (2). However, given the simplicity of the task used (i.e. no behavior improvement can be quantified) and the relatively short training duration, the finding is somewhat surprising and it would be useful to replicate it. Furthermore, a logical follow-up question is how long it would take for the training effect to disappear, i.e. CC value returning to pre-training level. In the present study, we replicated our previous finding of enhanced functional connectivity in a new cohort of subjects and, with additional post-training fcMRI acquisitions, we showed that the CC value returns to the pre-training level 4-5 min after the termination of the training.

METHODS: BOLD fMRI data (3.4x3.4x5mm^3 voxels, TE 25ms, TR 1000ms) were acquired in seven healthy *right-handed* adults using a 3T Philips MR scanner. All subjects (26±4 years old, 3 males and 4 females) completed two sessions. The first session included a pre-training and a post-training fcMRI run with a 23 minute gap (Fig. 1). During the 23 minute gap, the subject performed a unilateral (right-hand only) 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 right index finger as soon as they saw the crosshair dim (Fig. 1). The color change occurs every 27-32 seconds with randomized intervals. The two fcMRI runs before and after the motor training were performed with a similar protocol (fixation on a white crosshair, 21 axial slices) except that the pre-training fcMRI run lasted for 5 min while the post-training run lasted for 15 minutes. A longer duration was used for the post-training run so that we can assess the time courses of CC values during the post-training period. Another session (on a different day) was designed to identify left and right motor cortices (LMC and RMC) and only contained two motor fMRI runs. They used block-design of 20s finger tapping on both hands. This session was intentionally done separately with a minimum 24-hour gap to avoid potential confounding effects of motor training (in session 1) on the selection of motor cortex ROI, thereby avoiding possible circularity in the data processing. Postprocessing: All images were co-registered to the first image volume of the first fcMRI run. The motor fMRI data (from the second session) was used to identify motor cortices (Fig. 2A). An ROI covering the left motor cortex was manually drawn and the 400 voxels with the highest t-score were included in the final LMC mask (Fig. 2B) (2). Similar procedures were used to define the RMC mask (Fig. 2C). The LMC/RMC masks were then applied to the fcMRI data to obtain averaged time courses of left and right motor cortex, respectively. Then after respiratory correction, whole-brain fluctuation correction, low-pass filtering (<0.1Hz), baseline correction and normalization, the temporal signal remained is considered the resting state brain activity (Fig. 2D). Pearson CC between the two time courses from the LMC and RMC is calculated. For the post-training fcMRI data, two different methods of splitting the 15-min data were performed. In the first method, the 15-min data (900 volumes) were simply divided into three 5-min sub-runs and the CC value for each sub-run was calculated. In the second method, a moving-average approach was undertaken in which the data from 1-300 volumes were used to calculate a CC value, then the data from 2-301 volume were used to calculate another CC value, etc. We recognize that the adjacent CC values obtained from this approach are not independent, but it nonetheless provides a crude assessment of the temporal dynamics of the CC recovery during the post-training period.

RESULTS and DISCUSSION: Fig. 2D shows the averaged time courses of the fcMRI data during the pre-training period. Fig. 2E shows the comparison of CC values (n=7) and demonstrates an increase in CC with motor training (P=0.02). The training-related enhancement, however, did not last for a long period of time. In the next sub-run (i.e. data acquired 5-10 min after the training), the CC value had already returned to the pre-training level (Fig. 2E). During the next sub-run (i.e. data acquired 10-15 min after the training), the CC value did not change further and stayed at the pre-training level. Similar patterns are observed in the moving-average results (Fig. 3), which revealed that the CC values returned even earlier than that shown in the sub-run results. The functional connectivity is already at the pre-training level 4.5 min after the termination of the training.

The present study replicated our earlier report that a 23-min button-press motor training can alter functional connectivity in the bilateral motor cortex and further elucidated the temporal course of its return to baseline level upon training termination. These data suggest that the brain is constantly re-organizing itself based on life experiences and that a short-duration task is sufficient to leave a "foot-print" on the brain. However, if not maintained or consolidated, such alterations will disappear (also quickly) within a matter of a few minutes.

REFERENCE: (1) Tzur-Moryosef and Blumenfeld-Katzir, Proc. ISMRM. 18 (2010). P.2276. (2) Tung et al, Proc. ISMRM. 18 (2010). P.10.

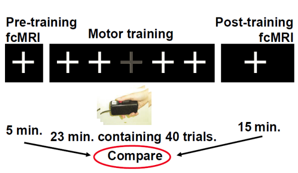


Figure 1. The paradigm. In this study, a comparison of pre- and post-training is made after a 23-minutes training session.

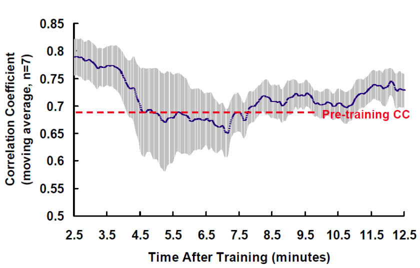
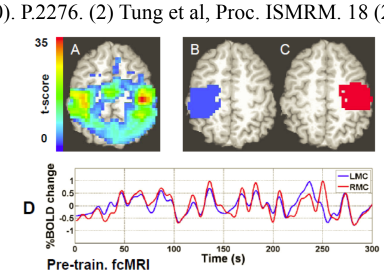


Figure 3. Moving average of CC. Red dash line indicates pre-training CC. (shade=std error, n=7). Starting time (2.5) is the mid-time of 1st 5-minutes post-train. fcMRI.



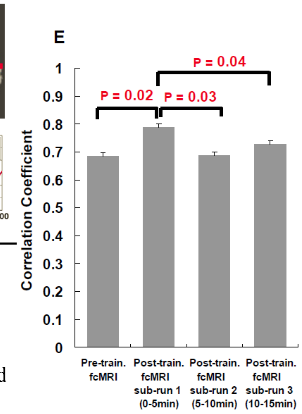


Figure 2. Motor cortex FC responded to training, then returned to its pre-training state. (A) Subject-specific t-score map identifying motor cortex. (B) LMC ROI. (C) RMC ROI. (D) BOLD time series from (B) and (C) in pre-training resting state, (E) LMC and RMC CC temporal trend (n=7, bar=std err.).