Short-Term Plasticity of The Motor System Induced by Piano Learning

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Introduction

The motor system is a cognitive domain that includes several cortical and sub-cortical regions and a well-defined fiber network that connects them. Diffusion MRI was recently shown to be sensitive to short term neuroplasticity (hours) in spatial navigation learning[1]. While learning of spatial information is expected to cause structural changes in limbic system structures (e.g. hippocampus, parahippocampal gyrus), the structural neuroplasticity aspects in higher cognitive domains are not straightforward. It is not clear, for example, if structural remodeling will occur when exposed to motor learning- and if it does occur will it affect the entire network. Thus in the current study we used DTI in order to investigate the neuroplasticity that accompanies sequential motor learning.

Methods

We set up a motor sequence learning task using an electric piano keyboard. 15 non-musician subjects were scanned before the task and immediately after it. During the task participant learned to play a short sequence based on the first 51 notes of Beethoven's *Für Elise*. Subjects were presented with an increasing number of notes on a virtual keyboard and were asked to repeat the sequence on the keyboard in front of them using their right hand. The presentation of a sequence included both visual and auditory stimuli. The task included 63 trials, starting with a single note and ending with the whole 51-notes piece. Subjects were tested on accuracy, timing and velocity of key pressing. The duration of the task was approximately 45 minutes.

The DTI protocol included diffusion weighted images with b value of 1,000 s/mm^2 at 30 directions and one b=0 image with isotropic resolution of 2.1 mm^3. DTI analysis included extraction of mean diffusivity (MD) and fractional anisotropy (FA) maps and normalization to the MNI coordinate system (based on the FA maps) using SPM. We then performed a voxelwise paired t-test on the diffusion MRI images. Clusters were considered significant when $P < 0.005$ and cluster size is larger than 15 voxels.

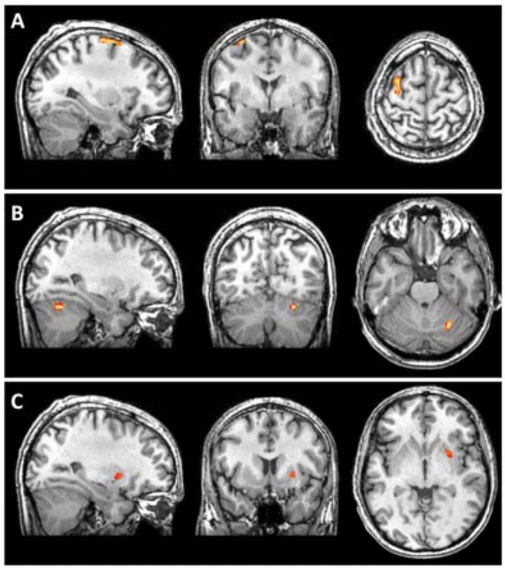

Figure 1. Reduction in mean diffusivity after 45 minutes of piano motor sequence learning was found in the left premotor cortex (A) and right cerebellum (B). An increase in fractional anisotropy was found in the right putamen (C).

Results

Behaviorally, all subjects improved their accuracy from trial to trial and by the end of the learning session succeeded to play most of the keys correctly (average of 47.5 ± 1.5 correct notes out of 51). While the improvement in accuracy was relatively high, the rhythm and timing of the subjects did not reach a reasonable amount of learning.

We found significant MD reduction in the left premotor cortex (P = 0.0004 in most significant voxel, see Fig. 1) and right cerebellum (P = 0.0005). We also found an FA increase in the right putamen (P = 0.0025) and in the right occipital cortex (P = 0.0002). In addition to changes in diffusion properties within gray matter regions, we also found evidence for plasticity within the left cortico-spinal tract: an increase in MD was found in the superior part, and a reduction in FA was observed within the middle section of the cortico-spinal tract (Fig. 2).

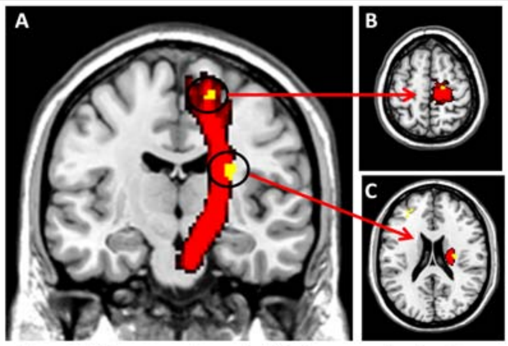

Figure 2. White matter changes in diffusion properties after 45 minutes of piano motor sequence learning are presented in coronal view (A). The cortico-spinal tract is presented in red, and significant clusters are presented superimposed in yelllow. An increase in mean diffusivity was found in the superior part of the tract (B), and a reduction in fractional anisotropy was found in its middle section (C).

Discussion

We showed here that DTI can follow on short-term learning-related brain plasticity of an entire cognitive domain - the motor system and pathways. One hour of learning was sufficient to cause structural brain changes in several motor system regions and within the cortico-spinal tract. As the micro-structural organization of the cortex, subcortical nuclei and white matter region is very different, it is not surprising that different diffusion properties changes were found in each one (e.g. decrease in MD in the pre-motor cortex, increase in FA in the putamen and the opposite effects in the cortico-spinal tract). The observed changes occurred after subjects improved their accuracy without any improvement in the timing of key pressing. It is possible that prolonged practice in the task, in which timing performance reach perfection as well, will result in different pattern of brain plasticity within the motor system. The ability to detect motor-system brain changes in such a short time scale may be able to shed light on the way neuroplasticity evolves within the system, and help to understand the role of each component of the system in behavioral processes.

References: (1) Sagi, Y., Tavor I., Hofstetter S., Tzur-Moryosef, S., Blumenfeld-Katzir, T., Assaf, Y. *Neuron* 73, 1195–203 (2012).