Diffusion MRI study of cortical plasticity induced by a short linguistic task

Shir Hofstetter[1,2], Naama Friedmann[1,3], and Yaniv Assaf[1,2]

[1]*Sagol School of Neuroscience, Tel Aviv University, Tel Aviv, Israel,* [2]*Neurobiology, Tel Aviv University, Tel Aviv, Israel,* [3]*School of Education, Tel Aviv University, Tel Aviv, Israel*

Introduction:

MRI offers a powerful tool to investigate neuroplasticity in the adult human brain. Most studies concerning cortical plasticity have shown morphometric alternation in cortical density after long term training of weeks to months[1]. A recent DTI study found changes in diffusion indices after 2 hour training, suggesting a more rapid timescale of neuroplasticity[2]. However, whether a short learning experience can induce microstructural changes in the neocortex is still unclear. Furthermore, in order to detect changes in the neocortex a higher scanning resolution is needed. Here we used diffusion MRI, a sensitive method of tissue's microstructure, to study cortical plasticity. In order to attain cortical involvement we used a short language task (under 1 hour).

Methods:

Word learning task: 15 adult participants (mean age 25.6) learned new words in their native language. Their goal was to learn 20 unfamiliar flowers names. Names were written on cards next to the flower picture. Training was divided into 6 sessions of 5 minutes. After each session, the participants were tested. They were presented with cards with the pictures of the flowers and were asked to write the flower's name on each card. Overall, the learning session took about 50 minutes. Participants were scanned before and immediately after the learning task.

Scanning protocol: **DTI** was acquired twice, with sagittal slices covering the left hemisphere in order to achieve better resolution. Matrix size was 128X128, resolution 1.5X1.5X2.1 mm^3, b value: 1000 s/mm2, 30 gradient directions and one b0 image. The composite hindered and restricted model of diffusion[3] **(CHARMED)** was also acquired with sagittal slices covering the left hemisphere**.** Matrix size was 160X160 (reconstructed to 256 X256), resolution 0.75 X0.75 X2.6 mm^3, max b= 3000, 34 different gradient directions and increasing b values (b= 1000, 200, 3000 s/mm^2) with 2 images at b=o. **SPGR**: whole brain axial slices were acquired twice. Resolution 0.8^3 mm^3, TR= 8.9960ms, TE=3.162ms.

Image processing: DTI analysis was done using Explore DTI[4]. CHARMED analysis included motion correction[5] of the high b value images, and analysis was performed according to the CHARMED framework[3] in order to extract maps of the restricted fraction (Fr).

Using SPM 8 and FreeSurfer we were able to extract masks of cortical regions of interest in the left hemisphere (fusiform gyrus, superior temporal gyrus (STG), middle temporal gyrus (MTG), inferior frontal gyrus (IFG), inferior-parietal gyrus and the hippocampus) in a different subject that served as template, and normalize all images and masks to MNI space. The normalized fractional anisotropy (FA) image functioned as the template. Participants' analysis: Fr maps were co-registered to their respective FA images. Each subject's FA image was first normalized to its matching mean image, and then to the template. Normalization was then written on mean diffusivity (MD), Lambdas and Fr images and smoothed before statistical analysis.

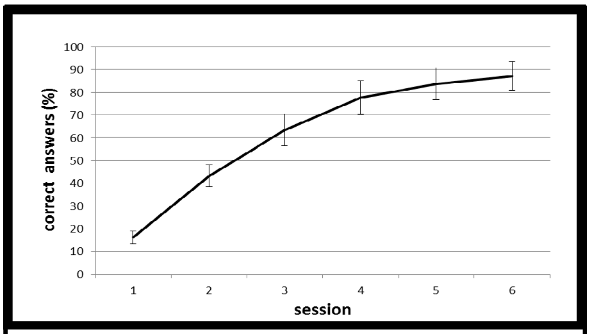

Figure 1: improvement in the learning task demonstrated by the percentage of correct answers in each session.

Results:

Participants showed continuous improvement in the learning task (Figure 1), indicating an aptitude of rapidly learning a language task. Since we were focused on specific regions related to the task, and in the interest of reducing statistical comparisons, voxel-based statistical analysis was restricted to specific regions using the template's cortical masks. Paired t-test was calculated using Matlab©, and a threshold of cluster>5 and p<0.001 was applied. Increase in MD was found in the hippocampus (3.5% s.t.e 0.88) and STG (2.87% s.t.e 0.53) (Figure 2: A,B). Lambda 1 (L1) significantly increased in the STG cluster, and radial diffusivity (RD) was increased in the hippocampus. Decrease in FA was found in the fusiform gyrus (-3.9% s.t.e 0.845) and IFG (-7.12% s.t.e 1.44) (Figure 2: C,D). Significant increase was shown in RD in the IFG. FR decrease was also found in the same cluster as the FA though with a less restricted p values (p<0.005).

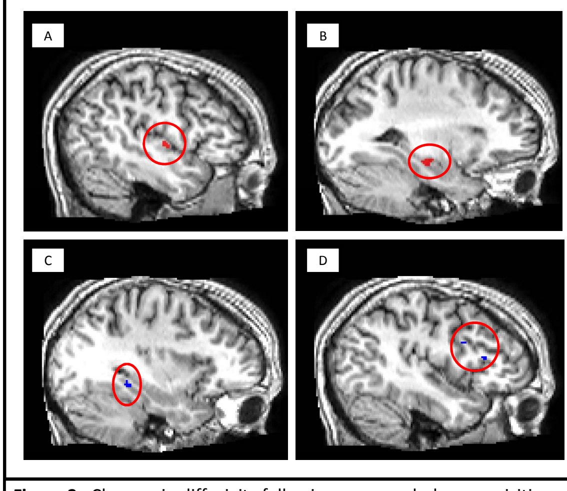

Figure 2: Changes in diffusivity following new vocabulary acquisition. Significant clusters are shown: MD increase in the (**A**) STG. (**B**) hippocampus. FA decrease in the (**C**) fusiform gyrus (**D**) IFG. (p<0.005 for illustration purposes)

Discussion:

These results show a first indication of cortical plasticity in the human brain after a short language learning task (introducing new lexical items to the lexicons). Using diffusion MRI we were able to detect microstructural changes in regions involved in language and reading. It seems that short training of less than an hour of high cognitive demand can induce microstructural changes in the cortex, suggesting a rapid time scale of neuroplasticity and providing additional evidence of the power of MRI to investigate the temporal and spatial progress of this process.

References:**1**. Draganski B, Gaser C, Busch V, et al. Neuroplasticity: changes in grey matter induced by training. *Nature*. 2004;427(6972):311–2. **2**. Sagi Y, Tavor I, Hofstetter S, et al. Learning in the Fast Lane: New Insights into Neuroplasticity. *Neuron*. 2012;73(6):1195–1203. **3**. Assaf Y, Freidlin RZ, Rohde GK, Basser PJ. New modeling and experimental framework to characterize hindered and restricted water diffusion in brain white matter. *Magnetic resonance in medicine*. 2004;52(5):965–78. **4**. Leemans A, Jeurissen B, Sijbers J and JD. ExploreDTI: a graphical toolbox for processing, analyzing, and visualizing diffusion MR data. In: *17th Annual Meeting of Intl Soc Mag Reson Med*. Hawaii, USA; 2009:3537. **5**. Ben-Amitay S, Jones DK, Assaf Y. Motion correction and registration of high b-value diffusion weighted images. *Magnetic resonance in medicine*. 2011.