# Gray Matter Differences due to weeks of Excessive Long-distance Running and after recovery revealed by Voxel-Based Morphometry (VBM)

**A. P. Wunderlich[1], S. Faust[2], W. Freund[1], U. Schütz[1], and C. Billich[1]**
[1]Dept. for Diagnostic and Interventional Radiology, Univ.-Clinic Ulm, Ulm, Germany, [2]Univ.-Clinic Ulm, Germany

**Purpose.** A voxel-based morphometry (VBM) study of local volume changes in gray matter during long-term long-distance running.

**Methods.** Ten experienced long-distance runners participating in the trans-european foot race were examined at 1.5T with a 3D T1w MP-RAGE sequence. Parameters were TR/TE/TI 2100/4.8/1060 ms, FA 15° and resolution of 1x1x1 mm. Acquisitions were performed a) before the run, b) after a distance of approx. 2400 km, and c) near the end of the race at approx. 4000 km. A fourth dataset was acquired in seven of the ten subjects after six months of recovery after the race during which the participants performed their usual training as before the run.
Data were processed and examined with SPM8 software (Wellcome Department of Imaging Neuroscience Group, London, UK; http://www.fil.ion.ucl.ac.uk/spm), using the VBM8 toolbox (http://dbm.neuro.uni-jena.de/vbm.html). Datasets were realigned and normalized to a MNI brain template. Gray and white matter were segmented automatically from all datasets. This resulted in probability maps in which each voxel value indicated the probability for gray and white matter, resp. Maps were smoothed with a Gaussian kernel of 12x12x12 mm, and only voxels with a probability of more than 25% for gray matter were considered. Statistical methods implemented in SPM gave significance of differences in gray matter volume between points of time. Total gray matter volume was used as a covariate to eliminate effects of global changes. A value of $p < 0.05$ corrected for multiple comparisons was chosen as significance threshold. Cluster threshold was set to 10 contiguous voxels. Brodman Areas (BA) coinciding with significant clusters were identified using the talairach daemon [1].

**Results.** After 4000 km, compared to beginning of the race, the main finding was reduction in volume of BA 18, 19 and 39 (Fig. 1). No local volume gain was found between these points of time. Between 2400 km and 4000 km, volume increased in the right prefrontal cortex (BA 8, 10 and 47; cf. Fig. 2, center). Occipital gray matter (BA 18, 19 and 39) volume reduction (Fig. 2, left picture) was more pronounced between these points of time compared to Fig. 1. No significant differences were found between the beginning of the race and after six month of recovery (data not shown).

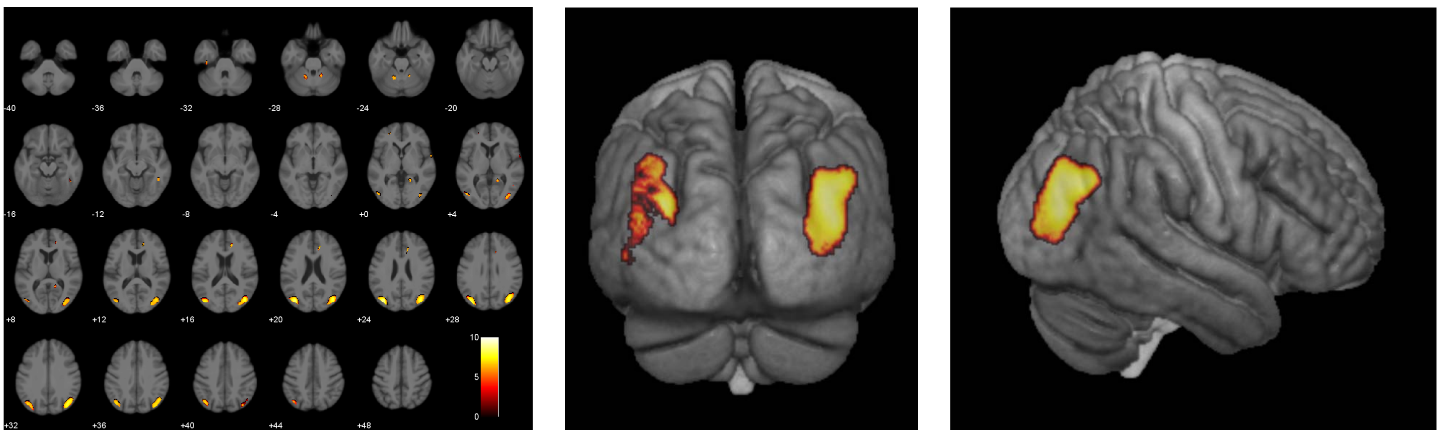

Fig. 1. Changes between before the race and after 4000 km. The only significant changes ($p<0.05$ corr.) are local volume reduction (yellow).

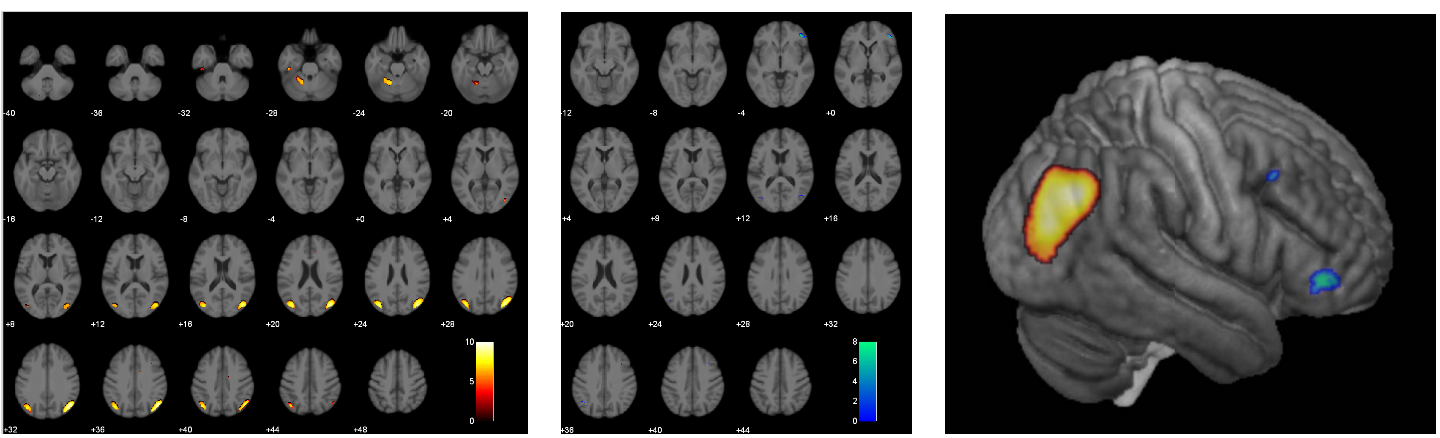

Fig 2. Changes between points of time after 2400 km vs. after 4000 km. Volume reduction (yellow) and gain (green) was observed at $p<0.05$ corr.

**Discussion.** The analysis was corrected for global brain volume changes due to running induced catabolism. Thus, volume reduction in visual fields (BA 18, 19 and 39) is thought to result from brain plasticity induced by reduced visual input and demands. That occurred mainly in the second half of the competition. BA 10 and 47, which showed a relative gain in volume during the second half of the race, have been associated to volition [2, 3]. Since there are no differences between before the race and six months thereafter (data not shown), we regard volume changes as reversible.

**References. 1.** Lancaster JL et al. Automated Talairach Atlas labels for functional brain mapping. Human Brain Mapping 10:120-131, 2000
**2.** J Lévesque et al. Neural Circuitry Underlying Voluntary Suppression of Sadness Biol Psychiatry 53:502–510, 2003
**3.** J. Lorenz et al. Keeping pain out of mind: the role of the dorsolateral prefrontal cortex in pain modulation. Brain 126 (5):1079-1091, 2003