Linking the Individual EEG Alpha Frequency to the Brain's Fibers

A. Federspiel[1], T. Koenig[1], T. Dierks[1], and K. Jann[1]
[1]Psychiatric Neurophysiology, University Hospital of Psychiatry, Bern 60, Switzerland

Introduction: The Individual EEG alpha frequency (IAF) correlates with subjects' performance in a diversity of cognitive tasks. However, the functional networks or the structural substrate underlying the inter-individual differences in IAF are largely unknown. Therefore, we conducted the present analysis to answer the question whether there are structural correlates in terms of white matter fiber trakts that are related to the subjects' IAFs.

Methods: IAF was determined in 21 healthy young subjects based on 92 channel eyes closed resting state EEG. Prior to imaging, a 92 channel scalp EEG (5kHz sampling rate, bandpass filter 0.1-250Hz, impedance below 20kΩ) was acquired during 6 minutes. Using Vision Analyzer (Brain Products, Gilching, Germany) the subject's IAF was calculated. Using a 3T Siemens scanner we first acquired T1 weighted anatomical images. Diffusion Tensor Imaging (DTI) was performed with a spin echo EPI using two 180° pulses (TR/TE 6500/96 ms, matrix 96x128, FOV 230x230mm, 52 slices, slice thickness 2 mm, gap 0 mm, pixel bandwidth 1396 Hz/pixel, N=2 averages). The trapezoidal diffusion sensitizing gradients were applied around the two 180° pulses at bvalue of 0 s/mm2 and at a maximal b-value of 1300 s/mm2 along 42 non-collinear directions.
The calculation and diagonalization of the diffusion tensor were based on the multivariate regression approach (1). Six independent elements of the diffusion tensor were extracted (2). Eigenvalues and eigenvectors were determined for each voxel, and fractional anisotropy (FA) values for each voxel was computed resulting in 2D FA maps. Co-registration of the 2-D FA maps to the 3-D structural images was performed using the scanner's slice position parameters of the SE-EPI measurements and the T1-weighted anatomical measurements. FA maps were transformed into the normalized Talairach space (3).High FA value indicates highly restricted diffusion, which is assumed to be caused by stronger myelination of white matter fiber tracts. The subjects' IAF were then voxel-wise correlated to their FA values.

Results: We found significant positive correlations along several fascicles, especially along the cingulum (Fig. 1), the arcuate fascicle (Fig. 2) and the internal capsule (Fig. 3). Interestingly, the correlations delineated fascicles that connect core regions of so called resting state networks (RSNs) (4), in particular of the so called default mode network (DMN) and the Working Memory Network (WMN). Fiber-Tracking based on the diffusion tensors starting at the PCC of the DMN respectively the left inferior frontal gyrus (LIFG) of the WMN revealed the above mentioned fascicles, thus confirming a structural-functional association.

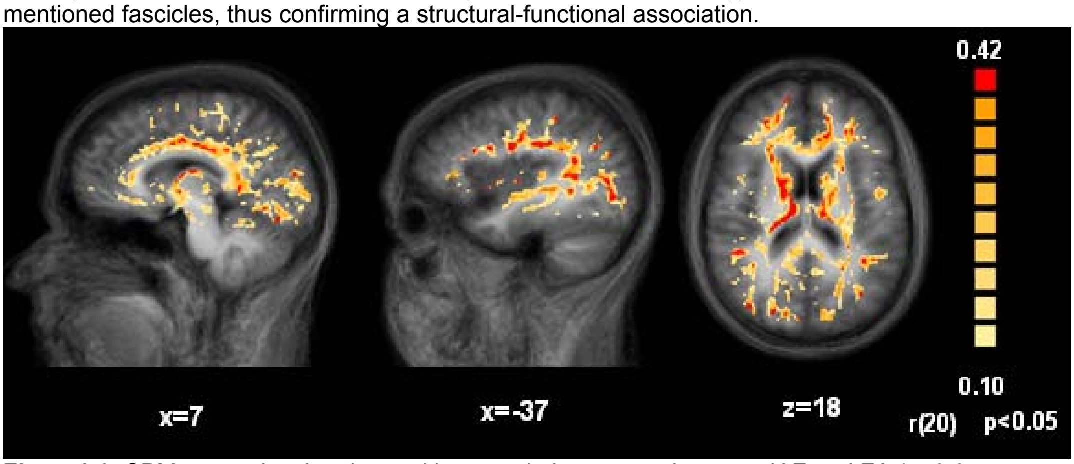

Figure1-3: SPM maps showing the positive correlation pattern between IAF and FA ($p<0.05$, uncorrected).

Conclusions: Our findings revealed a positive structural correlate of IAF differences in the cingulum involved in the DMN and in the arcuate fascicle associated with the left-WMN. Subjects with higher IAF tend to be faster and perform better in various cognitive tasks, especially working memory tasks. High directionality (i.e. high FA values) in white matter represents faster nerve-conduction. Therefore, our observations suggest that structural connectivity among task relevant areas affects processing capacity. Further support for this hypothesis evolves from patient studies. E.g. schizophrenic patients often show deficits in working memory tasks and exhibit altered FA values in the arcuate fascicle (5;6) as well as disturbed DMN connectivity. However, further investigation of such relationships is necessary.

References

1) Basser PJ, Mattiello J, LeBihan D. Estimation of the effective self-diffusion tensor from the NMR spin echo. J Magn Reson B 1994; 103(3):247-254. 2) Basser PJ and Pierpaoli C. Microstructural and physiological features of tissues elucidated by quantitative-diffusion-tensor MRI. J Magn Reson B 1996; 111(3):209-219. 3) Talairach J and Tournoux P. Referentially oriented cerebral MRI anatomy. Georg Thieme Verlag, Stuttgard, New York 1988; (1): 4) Jann K, Dierks T, Boesch C, Kottlow M, Strik W, Koenig T. BOLD correlates of EEG alpha phase-locking and the fMRI default mode network. Neuroimage 2009; 45(3):903-916. 5) Begre S, Kleinlogel H, Kiefer C, Strik W, Dierks T, Federspiel A. White matter anisotropy related to electrophysiology of first episode schizophrenia during NoGo inhibition. Neurobiol Dis 2008; 30(2):270-280. 6) Federspiel A, Begre S, Kiefer C, Schroth G, Strik WK, Dierks T. Alterations of white matter connectivity in first episode schizophrenia. Neurobiol Dis 2006; 22(3):702-709.