Spatio-spectral EEG Patterns of Intrinsic Connectivity Networks revealed by EEG/fMRI Measurements

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INTRODUCTION
Recent studies using fMRI revealed large scale intrinsic connectivity networks (ICNs) that show a correlated BOLD activity in the "resting condition" of the brain without a definitive cognitive task (Raichle, 2010). This finding offers a new window to the functional significance of the spontaneous Electroencephalogram (EEG) recorded during the resting state of the brain. The working hypothesis of this study is that spontaneous EEG signal contains, if not consists of, the electrical activity of the ICNs. Search for EEG correlates of ICNs might shed light on the working mechanism of these networks.

METHODS
Thirty-two healthy volunteers participated in the study (mean age 25.8 ± 4.7 years) with no history of neurological or psychological disorders. To create stationary segments of spontaneous and driven EEG rhythms, a block design has been applied with 3 blocks of 45 s of steady-state visual stimulation following 45 s of resting state (see Figure 1) for each of a series of visual stimulation frequencies between 4 and 46 Hz.

EEG was recorded simultaneously with fMRI using an MR compatible EEG amplifier (BrainAmp MR+, Brain Products, Germany) with 30 channels EEG (extended 10/20 system) and 1 channel ECG. The EEG was filtered between 0.1 and 250 Hz and sampled at 5 kHz. fMRI was recorded with a 3T7 MR scanner (Achieva, Philips Healthcare, Best, Netherlands) using T2*-weighted echo-planar imaging (TR 2981 ms, TE 50 ms, FA 90°). MRI related EEG artifacts were removed using Brain Vision Analyzer software (Brain Products, Germany) using the methods described in (Allen, 1998) and (Allen, 2000). Subsequently, physiological artifacts (movement) were marked on the data to be extracted from future analysis.

RESULTS
Default mode (DMN), somato-motor, left and right fronto-parietal (FP) and auditory networks in addition to 3 visual networks were identified in the sICA analysis of the fMRI (Figure 4).

The temporal correlations between the three courses of fMRI components and the band limited powers of the scalp EEG resulted in distinct spatio-spectral EEG patterns for each ICN in a range of frequency bands with stronger correlations in spatio bands (see Figure 5).

CONCLUSIONS
An individual ICN was reflected in multiple spatio-spectral EEG maps. However, the stronger correlations of each ICN and especially of distinct anatomical sub-components of an ICN with specific frequency bands, as for example the delta and gamma correlations for the anterior and theta-beta correlations for the posterior parts of DMN, indicate that they contribute to the wide-band EEG with specific topographic distributions. Previous EEG studies showed that cross frequency couplings play a role in interaction of neural networks of different scales (Demiralp, 2007b). Determining cross frequency phase-amplitude, phase-phase and amplitude-amplitude couplings in and between spatio-spectral EEG patterns of individual ICNs may reveal further information about the functioning of large scale networks.

REFERENCES