# fMRI BOLD correlates of Individual EEG Alpha Frequency reveal working memory and attention related Resting State Networks

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## Introduction

The individual EEG alpha frequency (IAF) is a potential marker for a person's cognitive abilities. Especially, it has been demonstrated that subjects with a higher IAF exhibit better performance in working memory tasks [1]. However, little is known about the functional networks that underlie the IAF. In a recent study we reported on IAF correlates with regional CBF in areas involved in attentional processes relevant for task execution [2]. While the previous study reports on IAF differences across subjects, we focussed in the present study on small intra-individual temporal variations of the IAF and its correlation with the simultaneously recorded fMRI BOLD signal. Besides this, there are recent reports on so called fMRI Resting State Networks (RSNs [3]) whereof some have been found to be involved in various task executions: the Dorsal Attention Network (DAN), the left Working (LWMN) Memory Network and the right Working Memory Network (RWMN). In the present study we aimed to answer the question whether intra-individual IAF variations are temporally and spatially associated to the respective RSNs,

## Methods

We performed simultaneous eyes closed resting state EEG-fMRI recordings in 20 healthy young subjects (10female/10male; mean age ± SD: 26 ± 3 years). This allowed us assessing slight IAF fluctuations over time in each subject and correlating it to fluctuations in the fMRI BOLD signal using a random effects general linear model. Functional MR data were acquired on a 3T Siemens Magnetom Trio Scanner using an echo-planar imaging sequence with prospective acquisition correction (EPI-PACE) and the following parameters: 252 volumes, 32 slices, 3×3×3 mm isovoxel, gap thickness=0.75 mm, matrix size=64×64, FOV 192×192 mm2, TR=1980 ms, TE=30 ms. Preprocessing involved slice scan-time correction, removal of low-frequency drifts, 3-D motion detection and correction, and spatial smoothing with an 8mm FWHM Gaussian Kernel. All data were normalized to standard Talairach space. EEG data were recorded from 92 scalp electrodes. Preprocessing included correction for artifacts (MR-scan pulse, cardioballistic and eye-movement artifact [4]), filtering between 8 Hz and 13 Hz (the EEG alpha frequency band) and segmentation of the EEG into epochs corresponding to single MR-volumes. In each segment the IAF was calculated using the state-state model variable Phi, which is an index for the dominant frequency in multichannel EEG data [5]. The Phi's calculated for each MR-volume were used as predictor for the fMRI BOLD signal after convolution with a standard HRF. In a second analysis we identified the three RSNs in our data sample (using ICA [6]) and computed the spatial similarity mean (SM) between the IAF BOLD correlates and each RSN.

## Results

Phi showed a mean intra-subject variance ± SD of 0.13 ± 0.08 and a mean inter-subject variance of 0.15 ± 0.39. The random effects GLM analysis revealed a symmetrical correlation pattern displaying significant positive correlations ($p<0.001$, corrected for type I errors at $\alpha<0.05$ using a cluster-size threshold of $162 mm^3$) in the superior and inferior frontal gyri, the middle temporal gyri, the anterior and posterior cingulate cortices and the left angular gyrus. The second analysis highlighted a positive association of the IAF correlates with the DAN (SM 0.18) as well as the two WMN (SM 0.21 and 0.17 for the left and the right WMN respectively). These SM values between IAF correlates and RSNs lay within the range of the inter-individual differences within the RSN themselves (DAN 0.29, LWMN 0.26, RWMN 0.21).

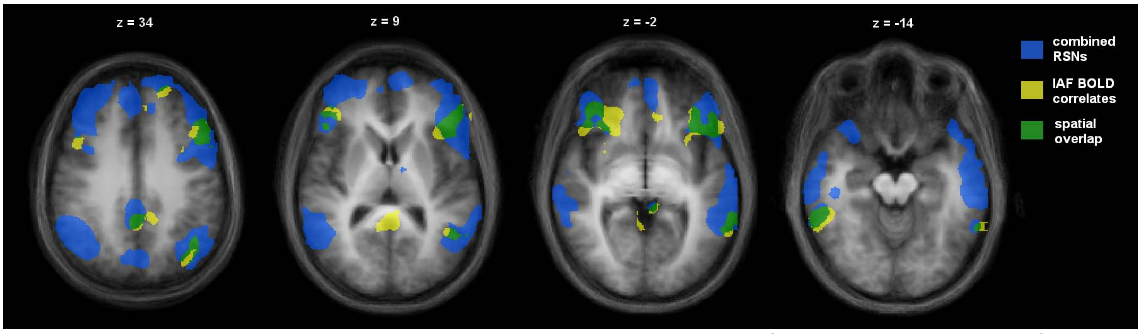


Figure 1: Illustrates the spatial overlap (green) between the combined RSNs (blue) and the IAF BOLD correlates (yellow).

## Discussion

The higher inter-individual variance of the Phi as compared to the intra-individual variance supports the use of IAF as an index for inter-individual differences. Furthermore, there is an association between IAF and RSNs known to be related to (working memory) task performance. These two observation taken together allows the conclusion that it is plausible that increasing IAF improves task performance because there is increased activity in the relevant functional networks.

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