Correlating EEG alpha-oscillations to brain perfusion – a simultaneous EEG and Arterial Spin Labelling study

T. E. Lund[1], K. Sidaros[1]

[1]Danish Research Centre for MR, Copenhagen University Hospital, Hvidovre, Denmark

Introduction

Recently a number of studies has been published where EEG-signal intensity in the alpha-band (8-13Hz) is correlated to variations in BOLD images [1-3] and near infraread spectroscopy measurements [3] (NIRS). A common finding from the three studies was negative correlation between power in the alpha band and the BOLD signal in occipital and parital areas. In the study of Goldmann [1] a positive correlation was furthermore seen between the power in the alpha band and the BOLD signal in the thalamus. As the BOLD signal is a complex composition of rCBF, rCBV and $CMRO_2$ effects a decrease in BOLD signal can not directly be interpretated as a decrease in rCBF. Another drawback of using BOLD weighted images for mapping spontaneus EEG-activity is its sensitivity to lowfrequency drifts in the scanner hardware, which makes highpass filtering a nescesary step in the processing of BOLD images in order to avoid false positives. In typical fMRI this is unproblematic as the experimenter controls the design of the paradigm, and can choose to make it of high enough frequency to avoid the highpass filter. In the study of spontaneous EEG-activity lowfrequency covariates of interest are not uncommon and further progress is likely to be dependent on the possibility of measuring slow temporal changes. Arterial Spin Labeling (ASL) is an MR method for measuring perfusion weighted images. Using difference images between labeled and unlabeled images it is almost insensitive to drifts in scanner hardware, and thus makes lowfrequency paradigms possible [4]. On the other hand ASL fMRI is less sensitive than conventional BOLD imaging. The purpose of this study was to investigate if combined EEG and arterial spin labeling was possible and whether the previously observed BOLD signal decreases can be attributed to a true rCBF decrease.

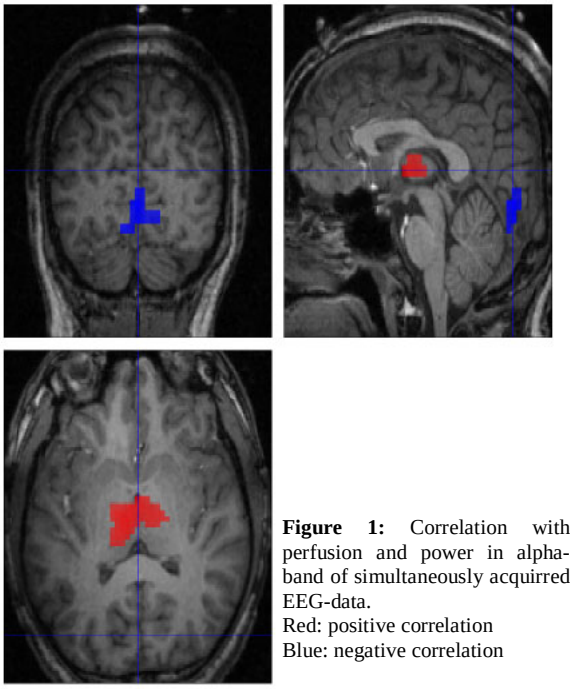

Figure 1: Correlation with perfusion and power in alpha-band of simultaneously acquirred EEG-data.
Red: positive correlation
Blue: negative correlation

Methods

One subject was scanned on a Siemens Magnetom Trio 3T scanner using a PICORE sequence [5] with the following imaging parameters: 18x5mm slices, 0.5mm slice gaps, TI/TE/TR =1300/24/2320ms, FOV=192mm, 64x64 matrix EPI readout, 900 repetitions. Flow-crushing gradients with a b-value of 8s/mm^2 were applied to suppress intra-vascular signal. Online retrospective motion correction was done using software on the scanner. Control and tag images were pair-wise subtracted giving an ASL time-series of 450 frames with a TR of 4640ms. The control and tag images were also averaged giving a BOLD-weighted time-series of 450 frames, but with non-optimal BOLD-parameters. EEG was acquired simultaneously with the ASL measurements using 32 channel EEG-recorder (Schwarzer EMR32, modified to a have a dynamic range of +/- 33 mV with a resolution of 1μV) at a sampling rate of 1kHz. Twenty five channels were used for EEG measurements, 1 was used to acquire a triggerpulse indicating the start of a new volume and 3 channels were used to acquirre two bipolar ECG channels. The EPI imaging artifact was removed using a volumewise artifact subtraction filter, and the pulse artifact was removed away using independent components. The filtering method has been published recently in [6]. Independent component analysis (ICA) was used to find independent components of alpha activity. The component beeing most specific to changes in alpha activity (determined from its spectrogram) was chosen for further analysis. The regressor of interest was constructed by convolving the log power of the spectrogram in the alpha-band (8-13 Hz) with a heamodynamic response function, and resampling the timecourse to that of the fMRI acquisition. Images were realigned and smoothed (FWHM=8mm) using SPM2 http://www.fil.ion.ucl.ac.uk/spm/spm2.html. BOLD and ASL images were analysed sepeartely (in SPM2), both using the same regressor of interest in a general linear model. In the BOLD analysis a high-pass filter cut-off of 128s was chosen, whereas ASL data remained unfiltered (temporally). T-contrasts were used to test for correlation and anticorrelation between the EEG data and MR images. Since a good prior hypothesis existed and small sensitivity was expected, ASL analysis was thresholded liberally with a threshold of p=0.01 and clustersize 10. For the BOLD analysis p=0.05 and clustersize 50 (False discovery rate corrected) was used.

Results

ASL: The EEG power in the alpha-band correlated positively with the perfusion in the thalamus, and negatively with the perfusion in the occipital cortex (see Figure 1). BOLD: The EEG power in the alpha-band correlated negatively with the BOLD signal in occipital- and parital cortex.

Conclusion

In the present study we have shown that EEG/ASL is possible and that previously observed negative correlations between EEG alpha-power and BOLD signal is likely to reflect true perfusion decreases.

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