Functional connectivity analysis is reliable in whole head near infrared spectroscopy

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Introduction: Correlation analysis of low-frequency fluctuations [1] in blood-oxygen level dependent (BOLD) fMRI data is known to yield functional connectivity maps. The procedure, also referred to as 'resting-state connectivity', does not rely on a specific task performance and has recently been successfully applied to optical tomography (OT) data [2,3]. OT is limited by low spatial resolution, why dense probe arrays had been used in [2]. However, full head coverage is desirable to avoid restrictions to specific networks. Here, we cross-validate functional connectivity analysis of near-infrared spectroscopy (NIRS) by simultaneous fMRI measurements and assess sparser topographical sampling still yielding results that are comparable to functional connectivity MRI. In a first step, we used a subset of optical fibers in a typical grid (2-3 cm inter-optode distance) covering both motor cortices. Such a grid can be extended to whole head coverage, without overly interfering with the subject's comfort.

Methods: The task consisted of 600 s scanning without task activation (eyes open) followed by a block-design finger-tapping task (25 trials, 10 s tapping, 10 s rest, left and right tapping in different sessions). The latter was included to functionally define a seed region of interest (ROI) in the motor cortex. fMRI data acquisition was performed on a whole-body 3T MAGNETON TIM Trio scanner (Siemens, Erlangen, Germany) equipped with a transmit/receive birdcage head coil. A gradient-echo EPI sequence was used (TE = 30 ms, BW = 116 kHz, voxel dimensions 3 x 3 mm², slice thickness 4 mm / inter-slice gap 1 mm). In the scan without task activation, we acquired 300 volumes (30 axial slices, TR 2, flip angle 78°). In the finger-tapping

experiments, 510 volumes were acquired (15 coronal slices through the motor system, TR 1, flip angle 62°). Optical data was acquired with a NIRScout 816 (2 wavelengths, 8 sources, 16 detectors, sampling frequency 6.25 Hz) produced by NIRx Medizintechnik GmbH, Berlin, Germany. The optical probes were integrated in a standard EEG cap which allows full head coverage and positioned over bilateral motor cortices (figure 1).

Figure 1: *Optical probes as worn by the subject inside the fMRI head coil. A standard EEG cap is used to position the sensors on the head.*

Optical data was low pass filtered (0.2 Hz) and attenuation was transformed to concentration changes of oxy- and deoxy hemoglobin using a modified Beer-Lambert law [4]. For the motor task we calculated a general linear model for fMRI and NIRS data separately. This provided us with the T-values for left and right finger tapping (figure 2 A). Correlation analysis of NIRS task independent data provided functional connectivity maps for the motor network and was used as a regressor in statistical analysis of the fMRI data. Thereby we can show correlations between both methods in the absence of a task and functional structures underlying the NIRS results.

Results: Motor activation yields to highly consistent results in both fMRI and NIRS (figure 2 A). Time courses of activation maxima in both measurement systems were correlated to gain their comparability (figure 2 B). This results in overwhelming high correlation with a correlation coefficient of 0.8 which is in good consistence with [5,6].

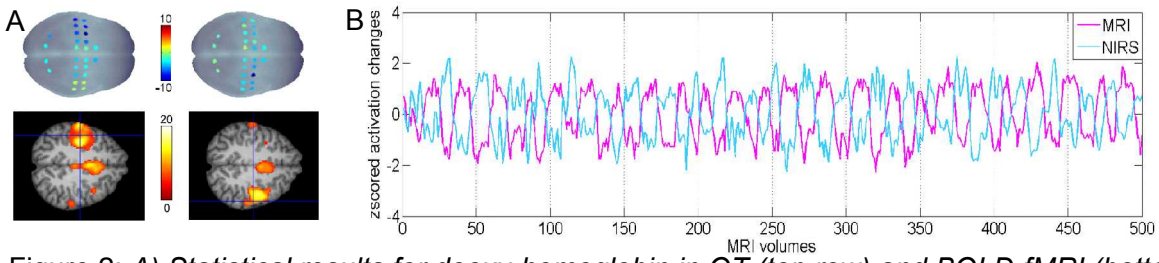

Figure 2: *A) Statistical results for deoxy-hemoglobin in OT (top row) and BOLD-fMRI (bottom row) for right and left finger tapping. Note that high activation is coded in blue (negative t-values) in the OT maps. The fMRI results show associated regions of the motor system (p<0.05, corrected). B) Time courses in the peak voxel / channel for deoxy-hemoglobin in OT and fMRI are anti-correlated with a correlation coefficient of -0.8.*

We selected the activation maxima in both systems as seed ROIs for the subsequent correlation analysis during the task independent measurement. Fehler: Referenz nicht gefundenThe inter-hemispheric correlation between motor cortices within NIRS data is quite high during rest. Surprisingly also the supplementary motor area (SMA) shows up (figure 3 A), which is deep in the inter-hemispheric fissure and thereby hard to find in optical data.

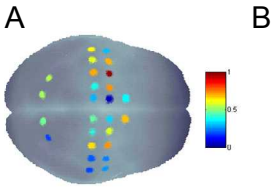

Figure 3: *A) Correlation of resting state deoxy-hemoglobin concentration changes. The peak channel for right finger tapping was used as seed (deep red). B) Correlation of resting state deoxy-hemoglobin concentration changes in the right peak channel with fMRI during rest. Correlation of the time courses is around -0.5.*

The correlation coefficient of the time courses in the described ROIs of both methods lowers to 0.5. This is less than during the task but differences in frequency bands show explanatory results. Using task independent NIRS data as a regressor in fMRI data reveals the assumed motor network (figure 3 B) with both motor cortices, SMA and Thalamus.

Conclusions: The current study establishes the feasibility of functional connectivity data analysis for topographical optode arrangements and thereby opens a perspective of whole-head measurements with NIRS. Due to its easy applicability, NIRS may develop into a tool for functional connectivity studies in subjects or patients not suited for fMRI experiments. The enquiry into changes of functional

connectivity during task performance and training may also profit from such an approach.

References:

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